AIR SEALING & INSULATION PRINCIPLES

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ABOUT SOUTHFACE

Southface promotes sustainable homes, workplaces and communities through education, research, advocacy and technical assistance.

WHO ARE YOU?

- Name
- Organization/company
- How long have you been in the design, construction, contractor or enforcement industry?

LEARNING OBJECTIVES

- Define the building envelope and identify the qualities of effective and ineffective building envelopes in homes
- Summarize the fundamental properties of air movement and describe the importance of air sealing to effective home performance
- Compare infiltration and controlled ventilation and identify the benefits of controlled ventilation for home performance
- Identify the code requirements for air sealing and identify accepted methods to verify air sealing for code compliance
- Discuss methods commonly used to perform air sealing in homes
- Explain the relationship between air sealing and insulation
- Define the methods of heat transfer
- Identify code requirements for insulation installation and describe the importance of insulation for home performance
- Summarize common methods and materials used to insulate new and existing homes
- Employ industry established inspection methods for determining the effectiveness of insulation installation

AGENDA

Morning (Air Sealing):

1. Introduction
2. The systems approach
3. The importance of air sealing
4. Infiltration vs. ventilation
5. Air movement
6. Code requirements
7. Practical air sealing

Afternoon (Insulation):

- Air sealing & insulation
- Importance of insulation
- Heat transfer
- Code requirements
- Installation
- Existing buildings
- Inspection

Please set phones to silent!
We will have breaks!

THE SYSTEMS APPROACH

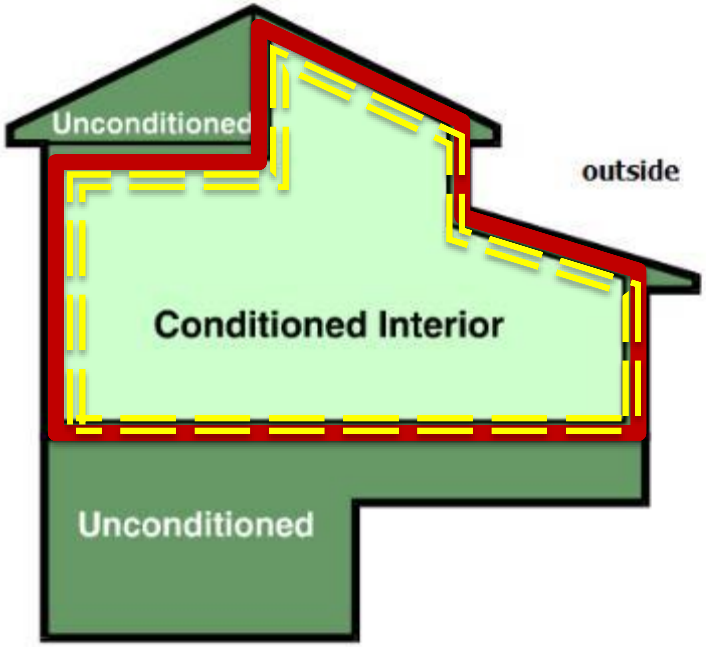
A house is a system made up of interrelated parts:

- The building envelope
- Heating & cooling
- Ventilation (controlled)
- Water heating & distribution
- Lighting & appliances

THE BUILDING ENVELOPE

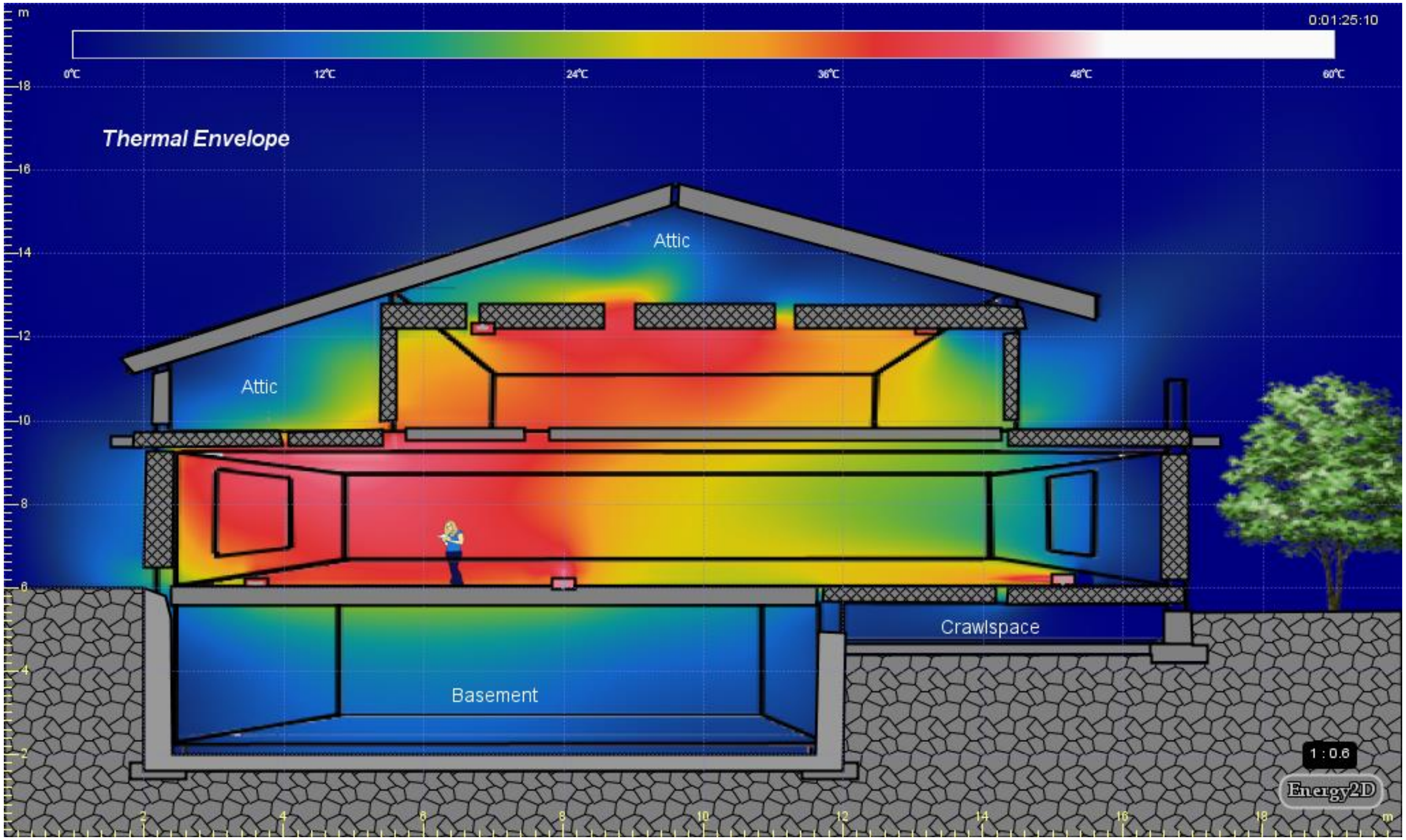
Building Envelope

- Continuous Air Barrier (Pressure Boundary)
- Complete Insulation Coverage (Thermal Boundary)



Thermal and Pressure Boundaries Make up the Building Envelope

THE IMPORTANCE OF AIR SEALING



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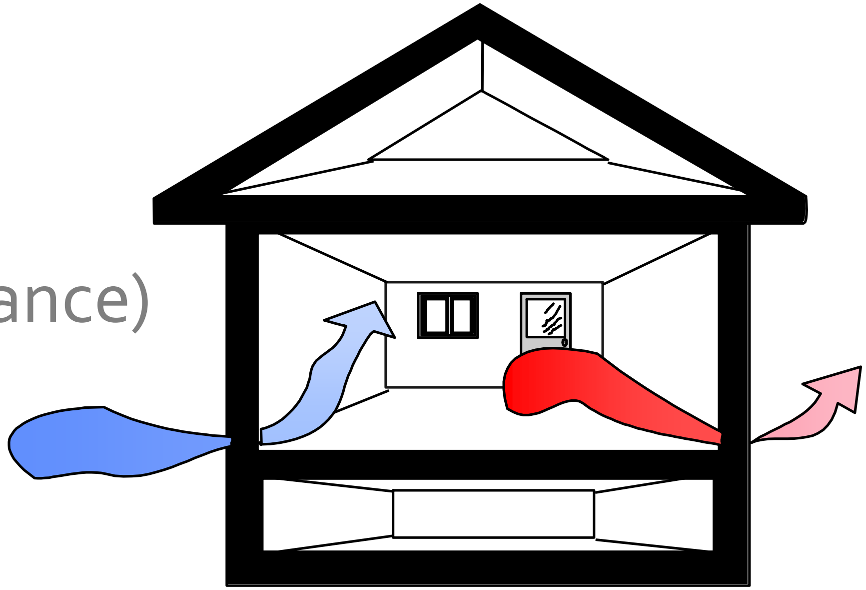
THE IMPORTANCE OF AIR SEALING

The effects of air leakage:

- Air carries heat, moisture & pollutants
- Transfers heat (directly & by reducing insulation performance)
- Causes poor comfort (heat & humidity)
- Moisture & pollutants affect Indoor Air Quality (IAQ)



AIR MOVEMENT – BASIC TERMS

Infiltration: Unintentional air movement into a building (drafts)

Exfiltration: Unintentional air movement out of a building (drafts – again)

Ventilation: Intentional & controlled air movement into and out of a building designed to provide fresh air to the occupants (healthy indoor air quality)

Air Changes*:* Air entering and leaving a building, replacing the inside air with air from the outside.

ACH: Air Changes per Hour – a rate of air exchange

CFM: Cubic Feet per Minute – a rate of air movement

Every time air enters a building, air will also exit the building at a different location– infiltration and exfiltration always happen simultaneously

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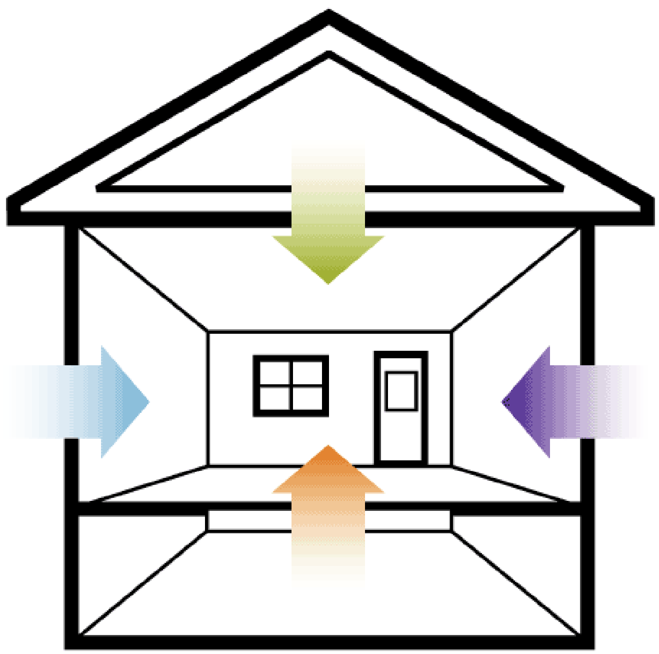
CAN YOU BUILD A HOUSE TOO TIGHT?

WHERE DOES THE "FRESH" AIR COME FROM?

ATTIC

Insulation fibers, dust, coal soot, rodent scat



OUTSIDE

Pollen, auto fumes, dust, moisture

GARAGE

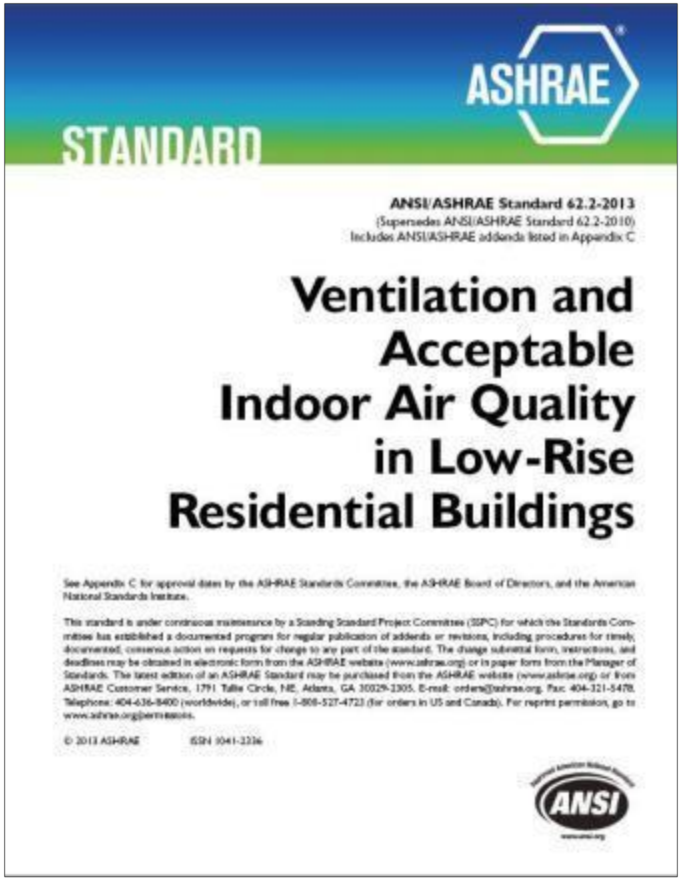
Carbon monoxide, pesticides, gasoline, fertilizers

CRAWLSPACE

Mold, dust, lead, radon, moisture, termiticide

Build tight, Ventilate right

ASHRAE STANDARD 62.2



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2013
(Supersedes ANSI/ASHRAE Standard 62.2-2010)
Includes ANSI/ASHRAE addenda listed in Appendix C

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

See Appendix C for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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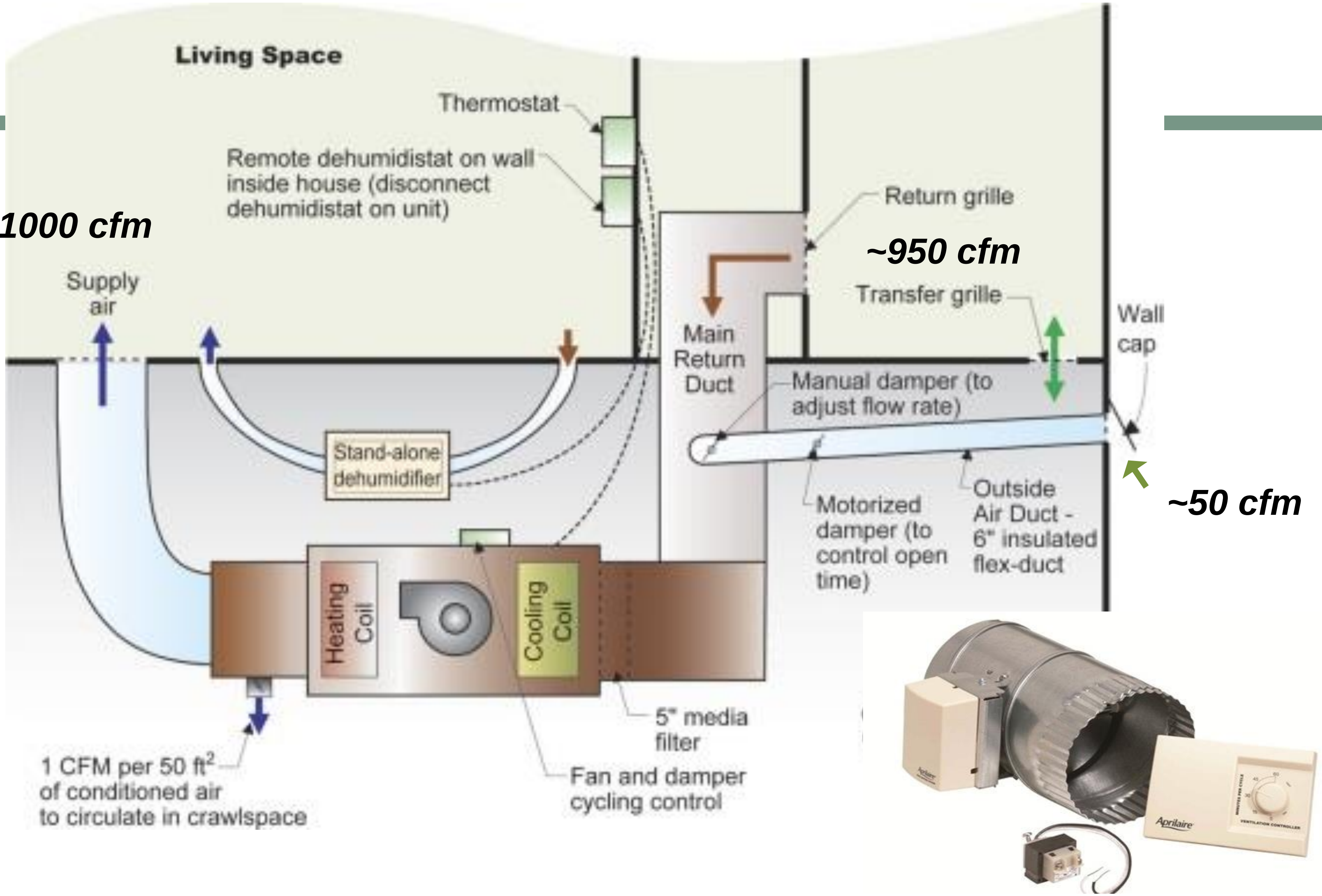
ANSI

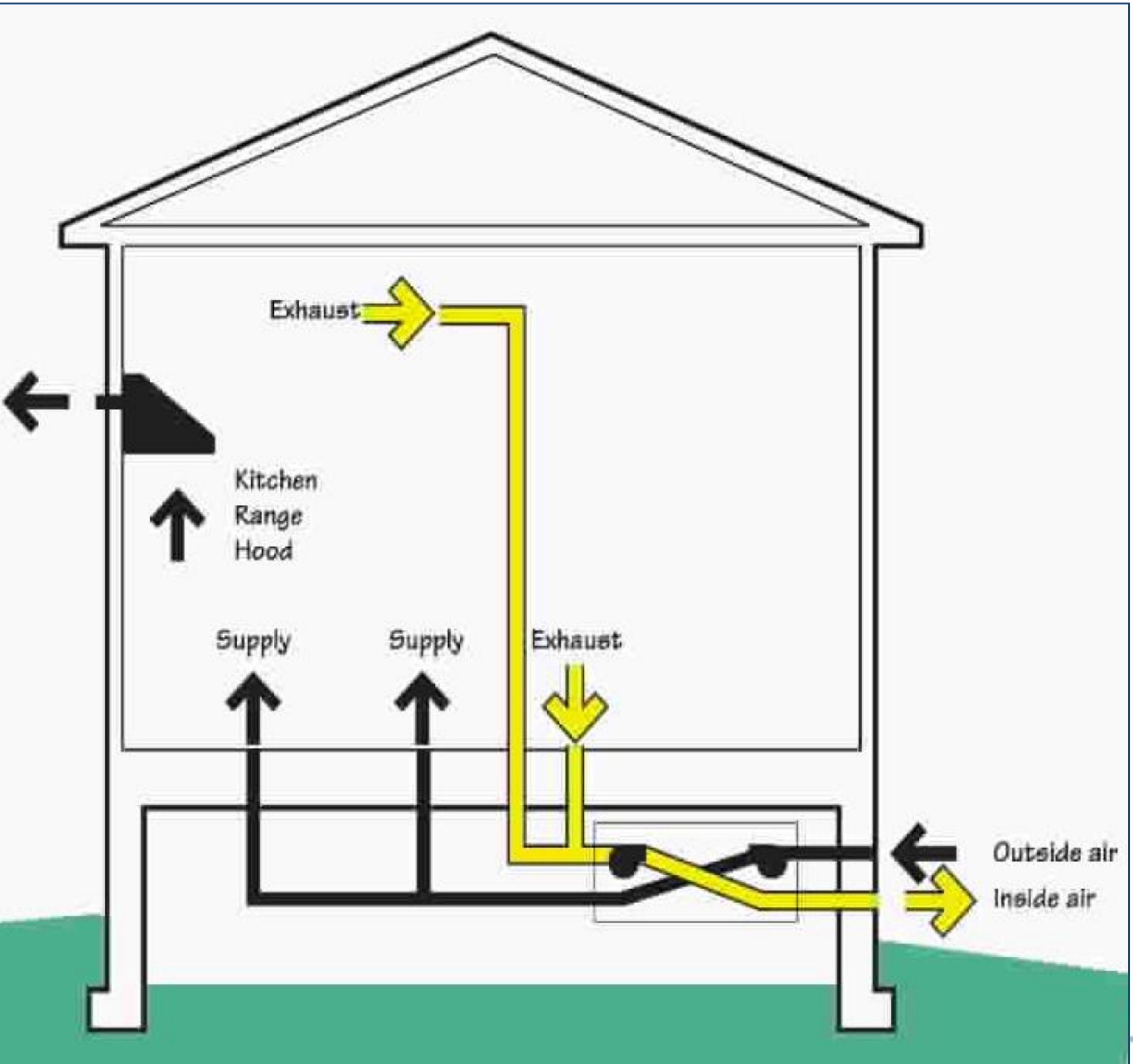
ASHRAE 62.2-2013
7.5 cfm/person + 3 cfm / 100 s.f.

SUPPLY - POSITIVE PRESSURE VENTILATION



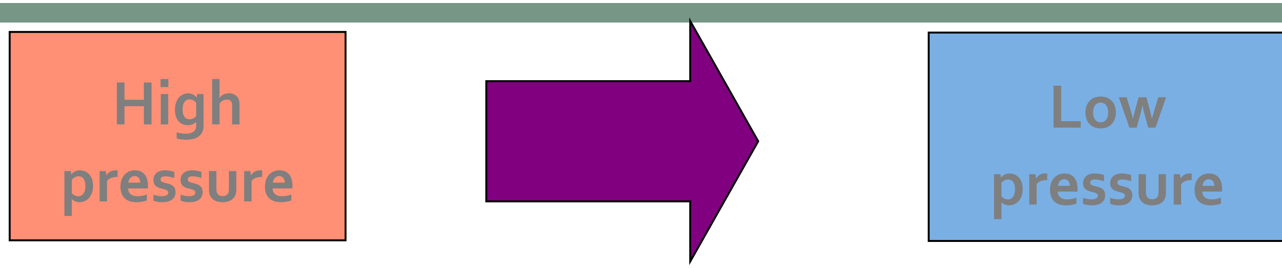
Positive Ventilation Supplied via O.A. Ducted to Return

Balanced Ventilation



Energy Recovery Ventilator (ERV) – transfers both heat (Sensible) and moisture (Latent)

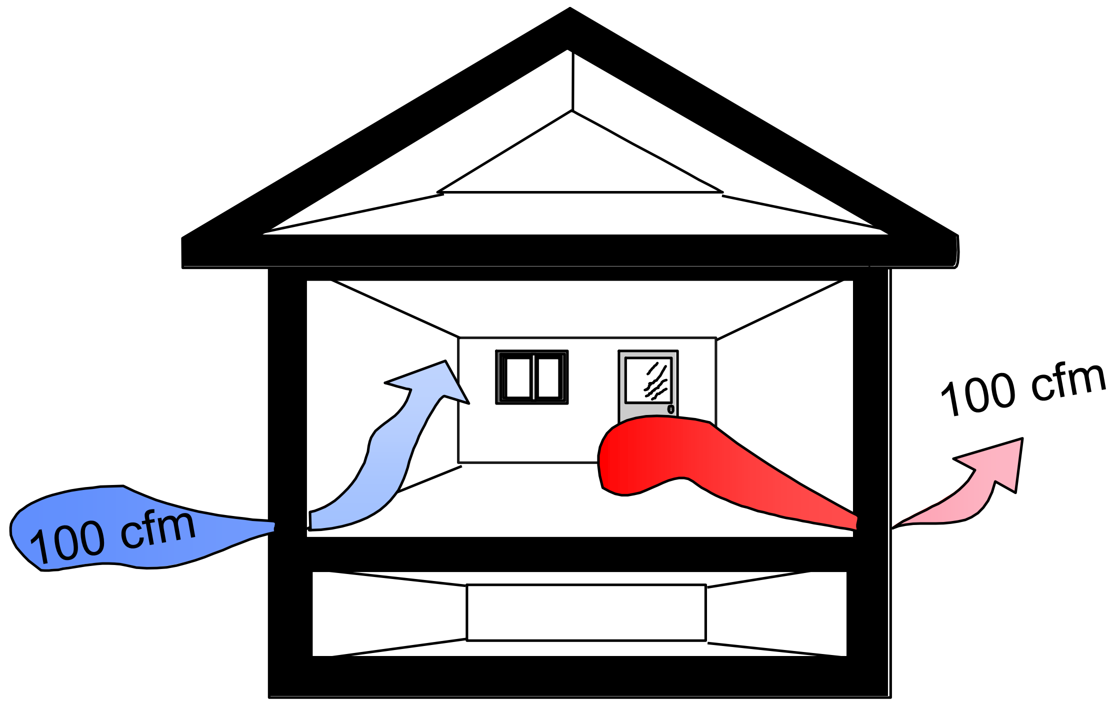
AIR FLOW



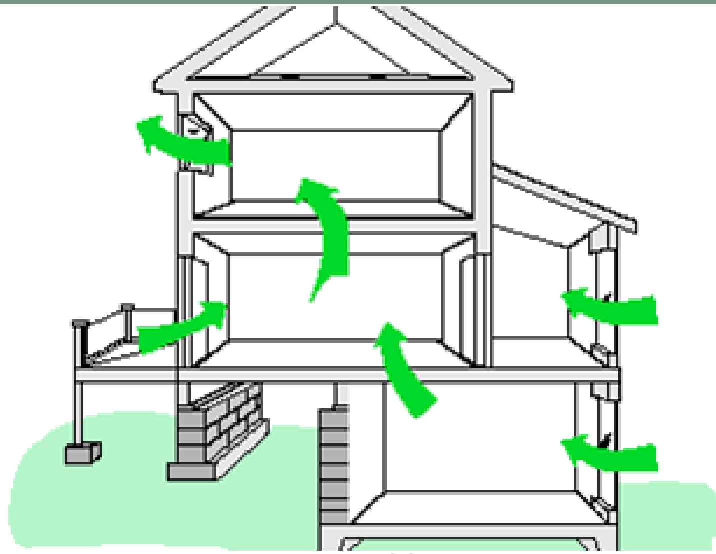
Conditions for Air Infiltration

- Pathways for air movement (hole)
- Pressure difference (driving force)

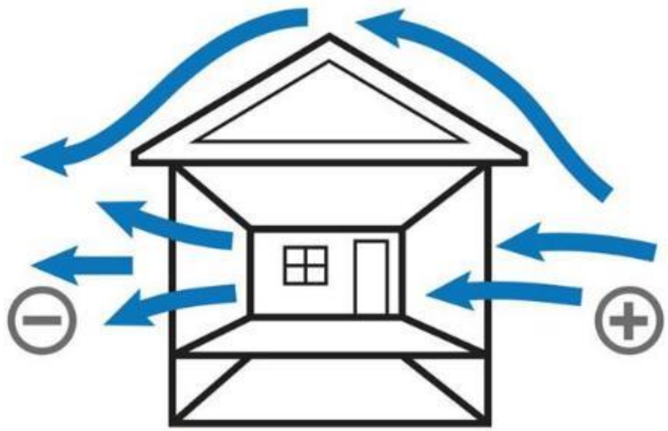
Quantity of air out = quantity of air in



WHAT DRIVES AIR MOVEMENT?



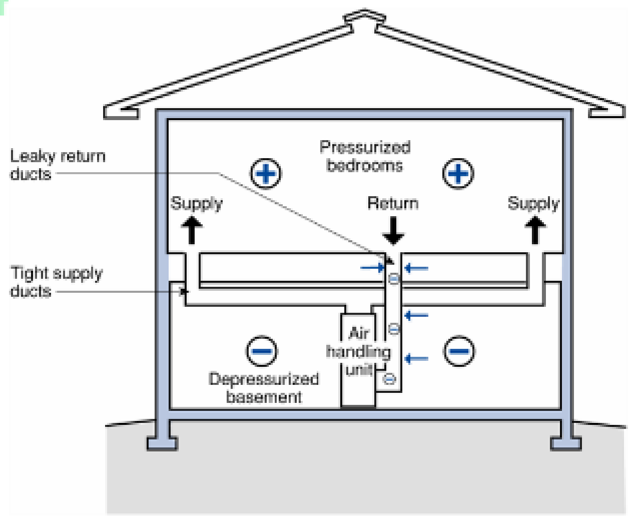
Stack Effect



Wind

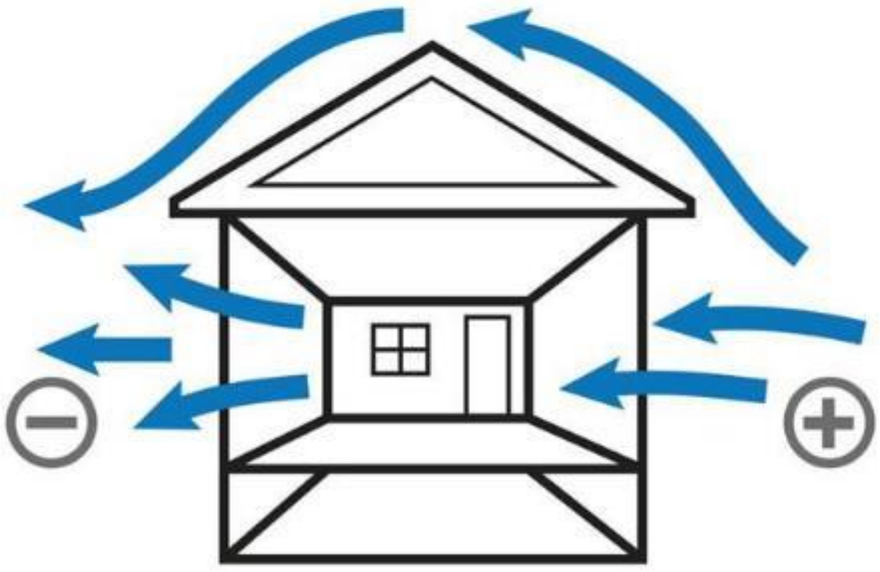
Things that create pressure differences

(natural & mechanical)

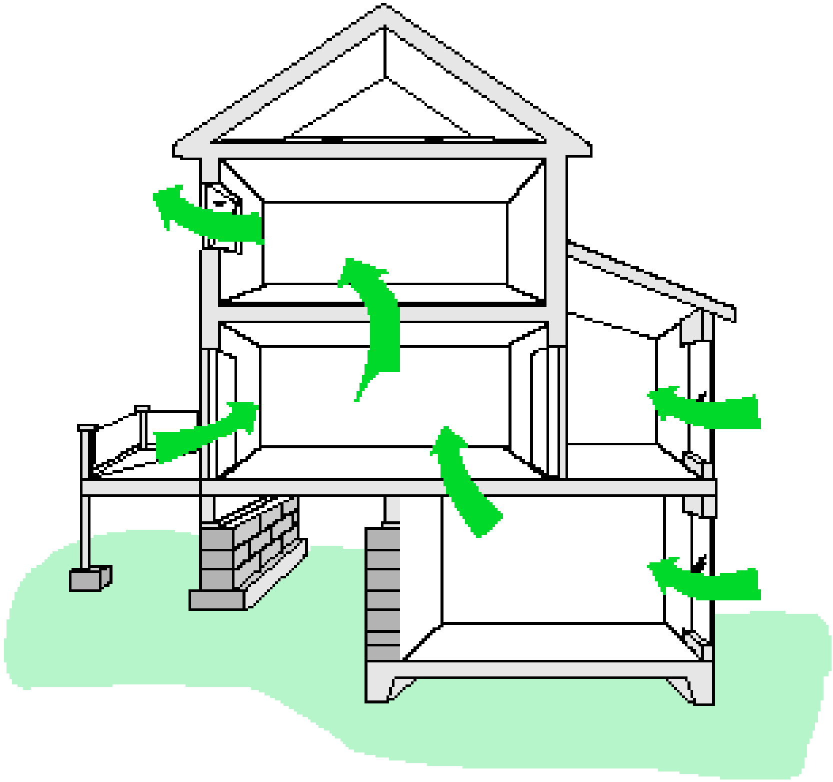


Mechanical Systems

NATURAL DRIVING FORCES FOR INFILTRATION



Wind



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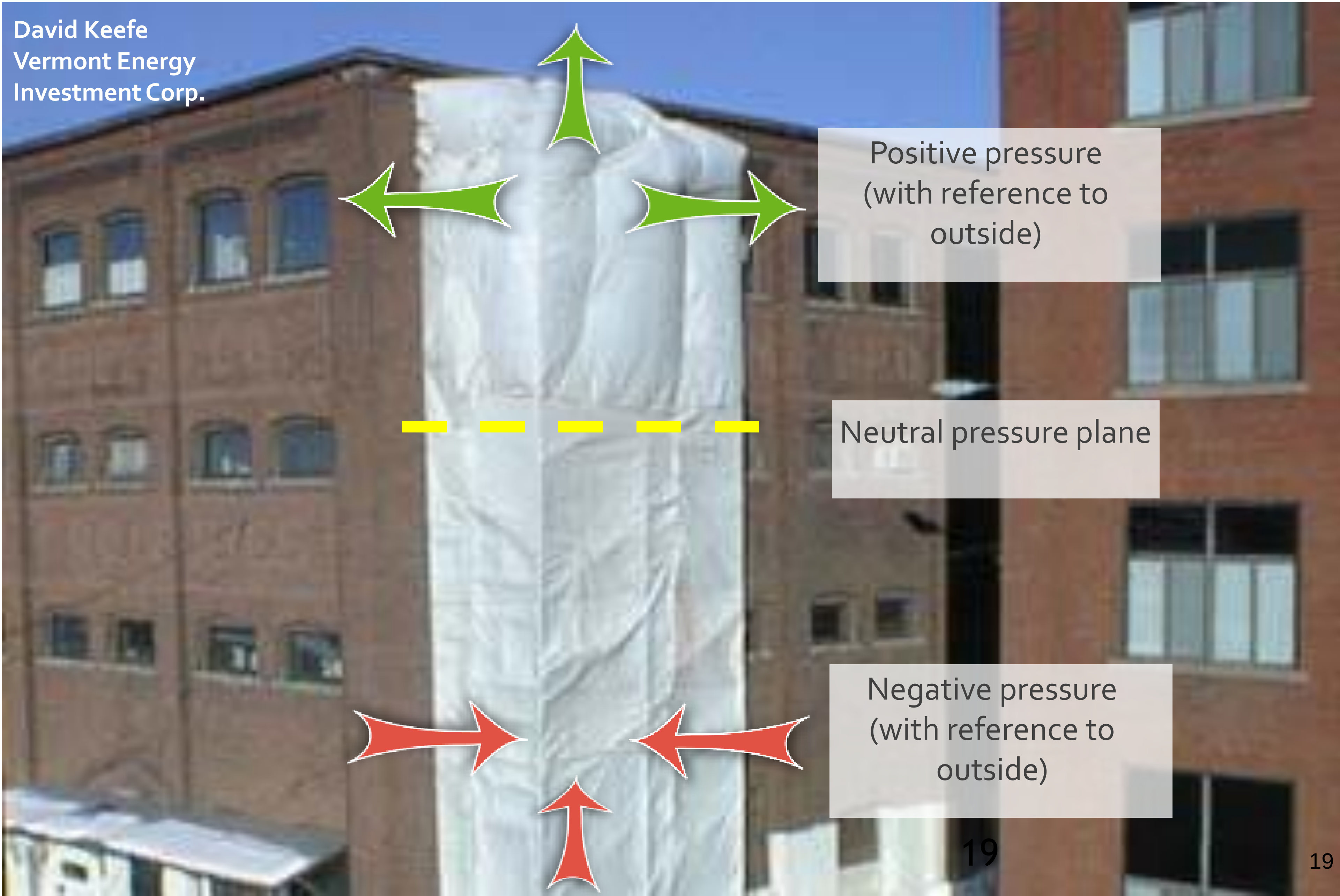
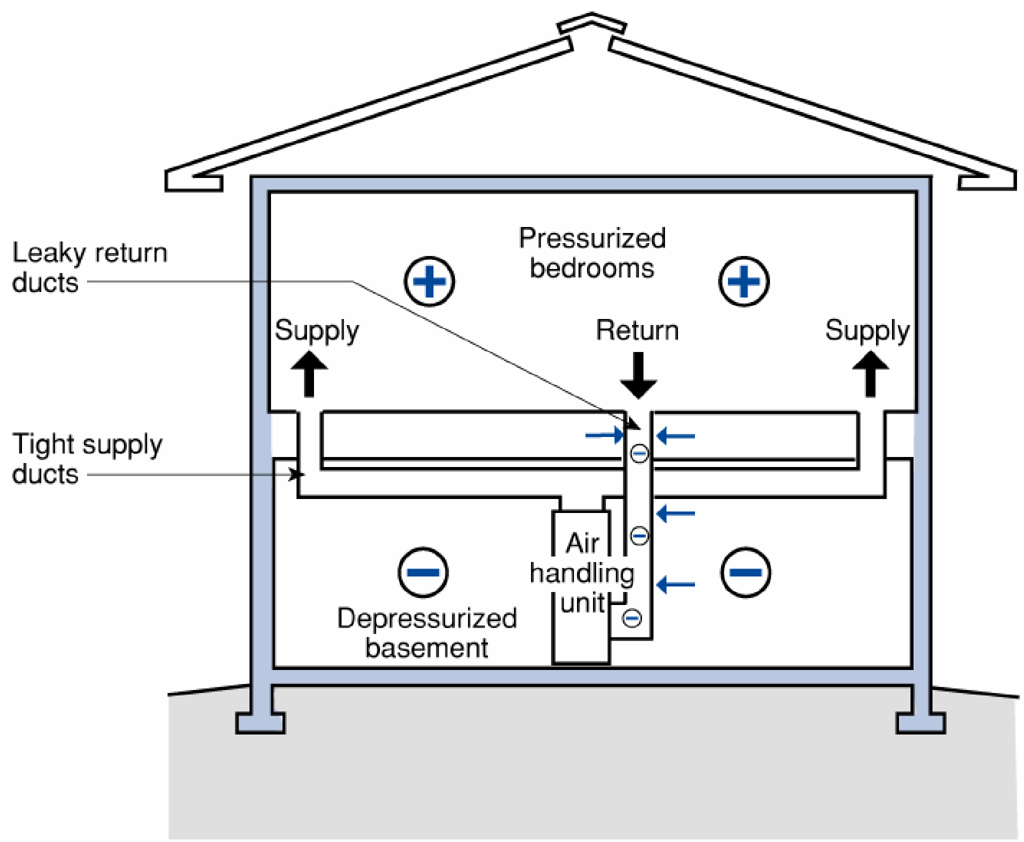


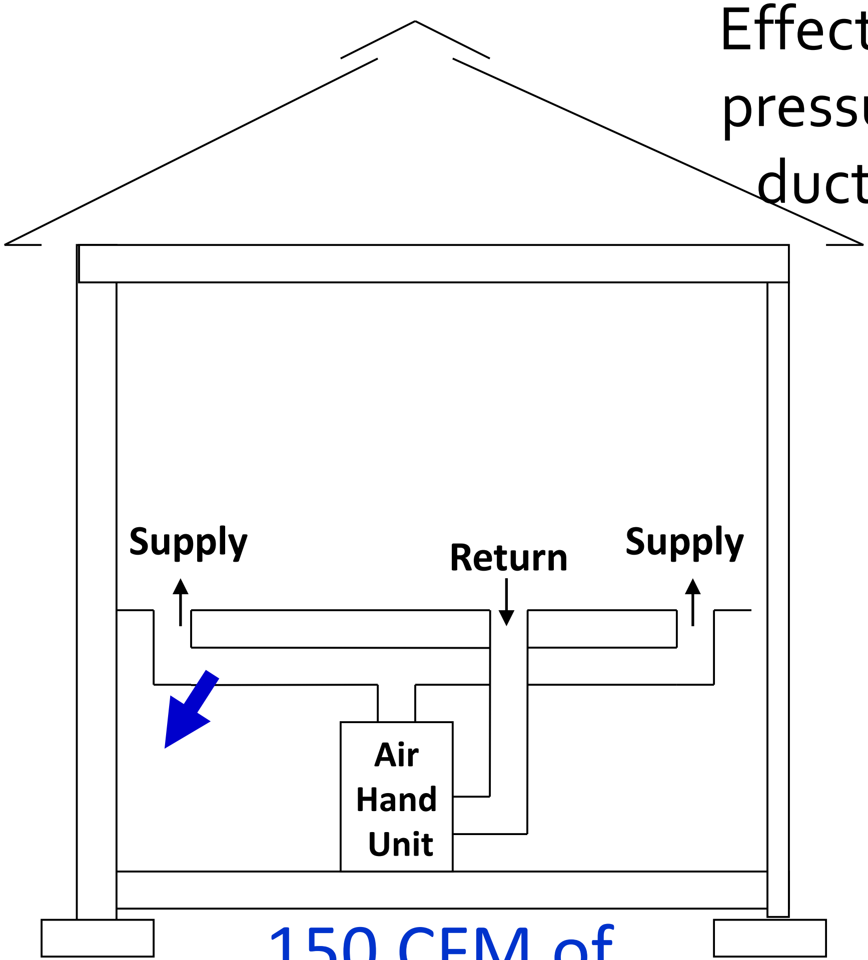
FANS—DRIVING FORCES FOR INFILTRATION

Device	CFM
Bath	50
Range hood	150
Downdraft hood	500
"Emeril" Hood	1500
Dryer	200
Air Handler	400 / ton

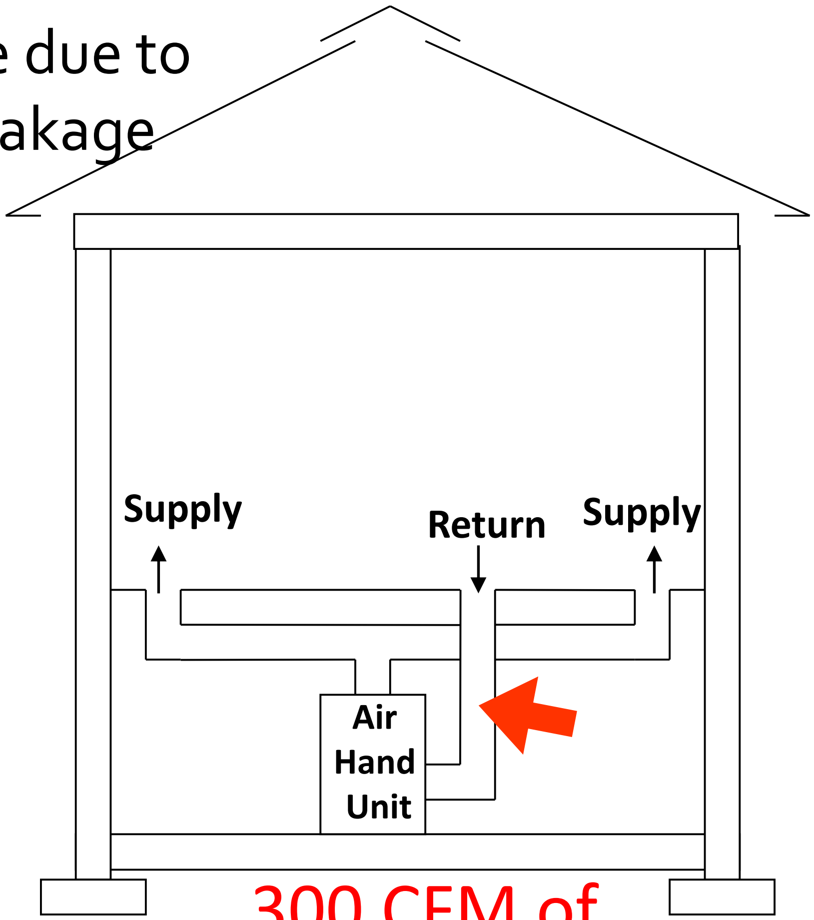


DUCT LEAKAGE—
DRIVER FOR INFILTRATION

Effect on house pressure due to duct leakage



150 CFM of leakage in supply

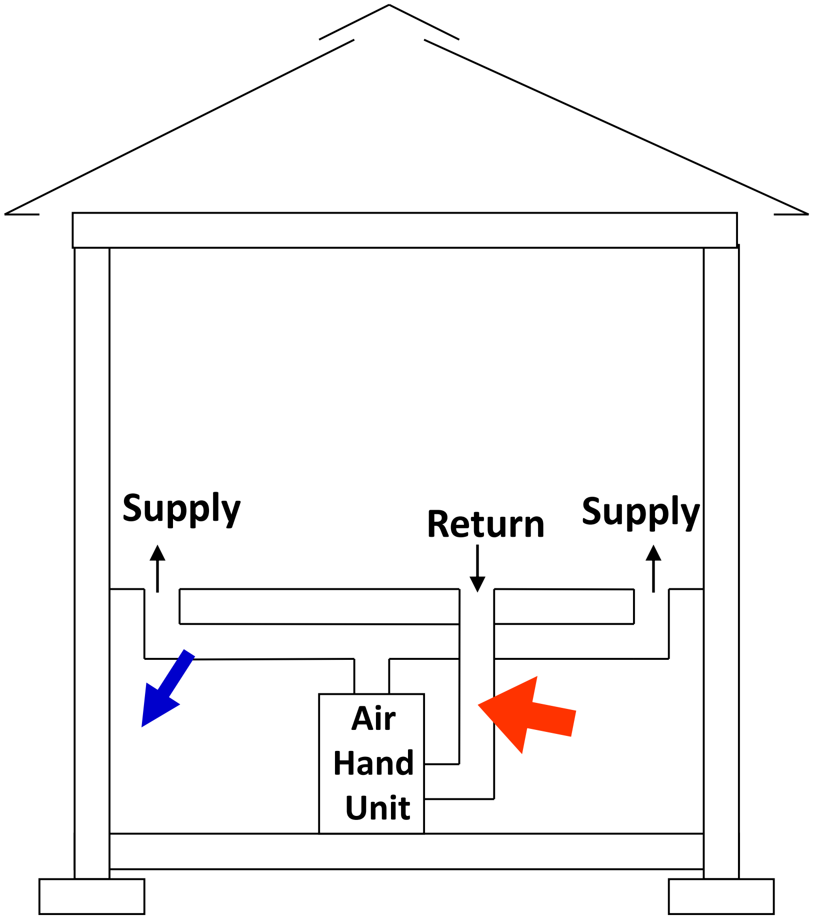


300 CFM of leakage in return

DUCT LEAKAGE—
DRIVER FOR INFILTRATION

Dominant Duct Leakage

What is the net effect on House pressure due to 150 cfm of supply and 300 cfm of return duct leakage?



150 CFM of leaks in supply &
300 CFM of leaks in return

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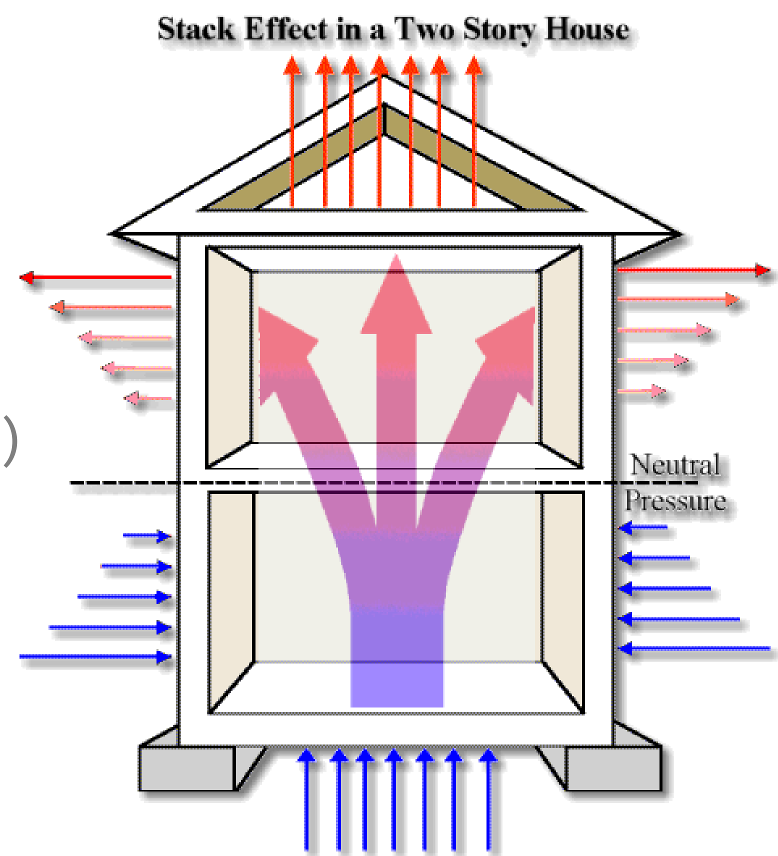
AIR SEALING

Priorities for air sealing:

1. Between house & garage
2. Leaks high in the structure (attic)
3. Leaks low in the structure (crawlspaces)
4. Everything else in between



402.4 AIR LEAKAGE

Mandatory Requirement: Air Sealing

- Detailed list
- Fireplaces
- Fenestration
- Recessed light fixtures: airtight, IC-rated

402.4 Air leakage (Mandatory).

402.4.1 Building thermal envelope. The *building thermal envelope* shall be durably sealed to limit infiltration. The sealing methods between dissimilar materials shall allow for differential expansion and contraction. The following shall be caulked, gasketed, weatherstripped or otherwise sealed with an air barrier material, suitable film or solid material:

1. All joints, seams and penetrations.
2. Site-built windows, doors and skylights.
3. Openings between window and door assemblies and their respective jambs and framing.
4. Utility penetrations.
5. Dropped ceilings or chases adjacent to the thermal envelope.
6. Knee walls.
7. Walls and ceilings separating a garage from conditioned spaces.
8. Behind tubs and showers on exterior walls.
9. Common walls between dwelling units.
10. Attic access openings.
11. Rim joist junction.
12. Other sources of infiltration.

2009 IECC- SECTION 402.4.2

Two options to prove air sealing:

$$ACH_{50} = \frac{CFM50 \times 60}{Volume}$$

1. Testing of house leakage
   - Blower door result must be less than 7 ACH_{50}
2. Visual Inspection
   - No ACH_{50} requirement
   - Use Code Checklist (thermal bypass)
   - Requires multiple inspections
     - Framing stage / pre-drywall
     - Final

NUMBER	COMPONENT	CRITERIA
1	Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air permeable insulation is not used as a sealing material. Air permeable insulation is inside of an air barrier.
2	Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed. Attic access (except unvented attic), knee wall door, or drop down stair is sealed
3	Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed
4	Windows and doors	Space between window/door jambs and framing is sealed.
5	Rim joists	Rim joists are insulated and include an air barrier.
6	Floors (including above-garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of insulation.
7	Crawl space walls	Insulation is permanently attached to walls. Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped
8	Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed
9	Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
10	Garage separation	Air sealing is provided between the garage and conditioned spaces.
11	Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall Exception fixtures in conditioned space.
12	Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
13	Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
14	Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed
15	Common wall	Air barrier is installed in common wall between dwelling units.
16	HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
17	Fireplace	Fireplace walls include an air barrier.

INSULATION AND AIR SEALING

TABLE 402.4.2
AIR BARRIER AND INSULATION INSPECTION COMPONENT CRITERIA

COMPONENT	CRITERIA
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material. Air-permeable insulation is inside of an air barrier.
Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed. Attic access (except unvented attic), knee wall door, or drop down stair is sealed.
Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
Floors (including above-garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of insulation.
Crawl space walls	Insulation is permanently attached to walls. Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed.
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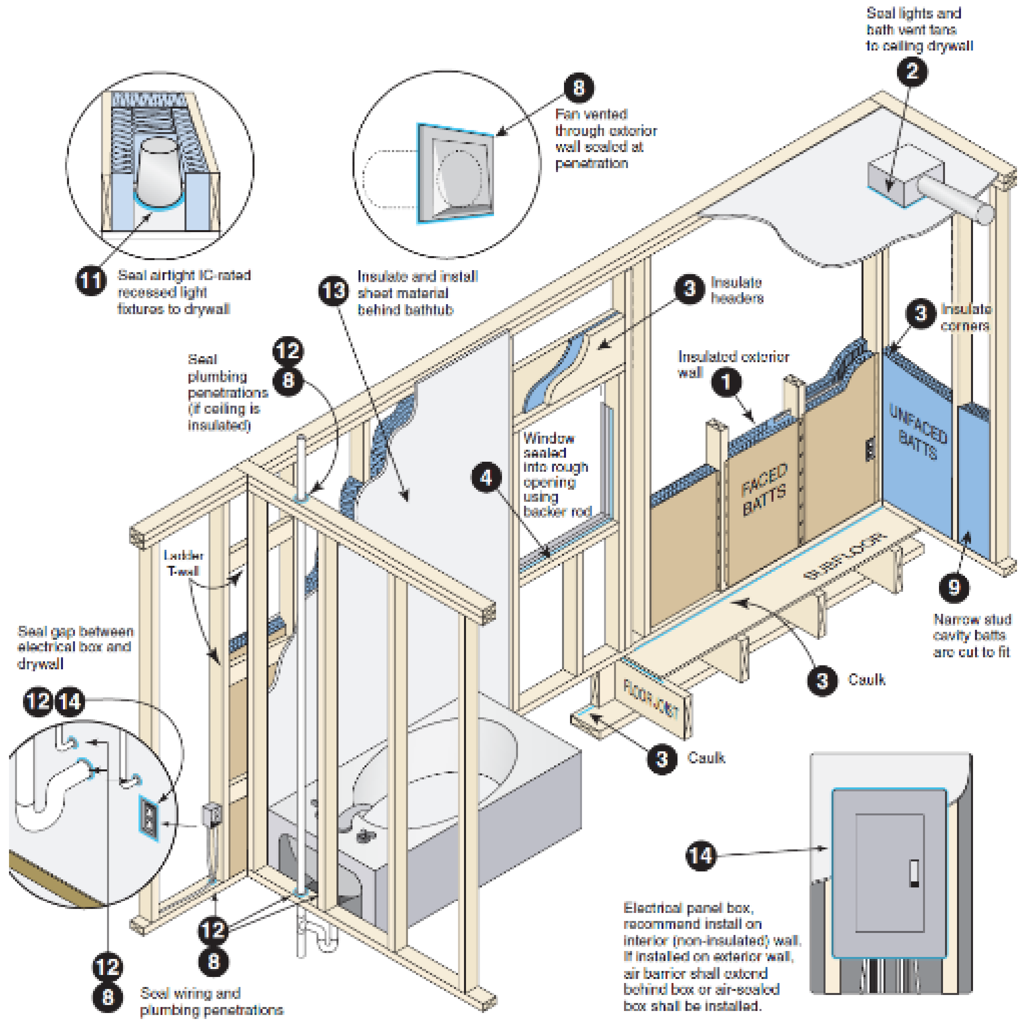
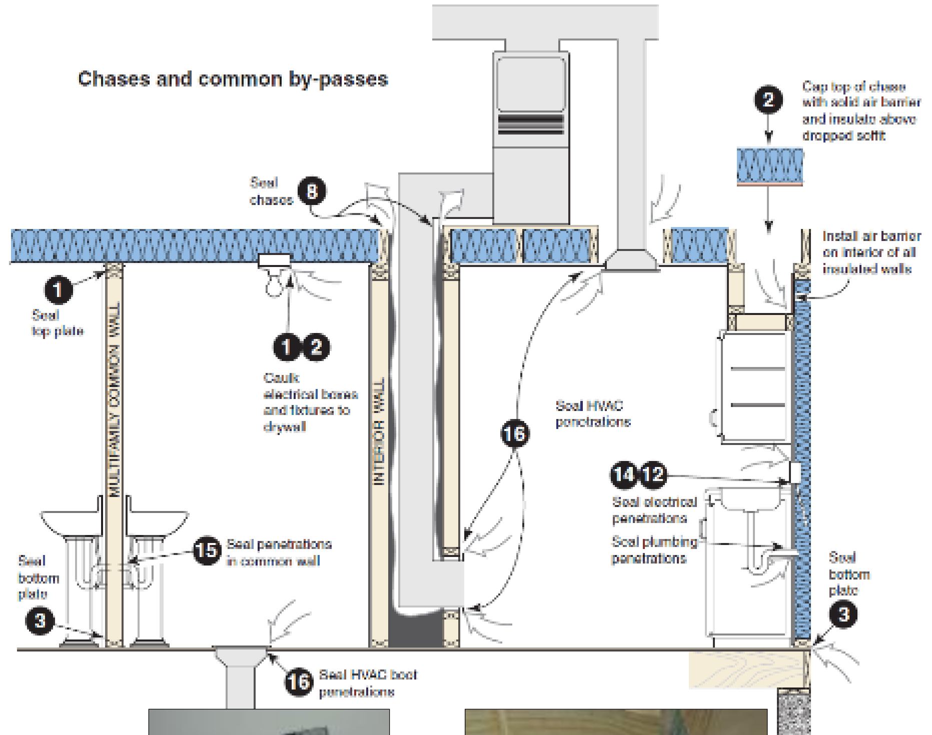
Fireplace	Fireplace walls include an air barrier.

AIR SEALING

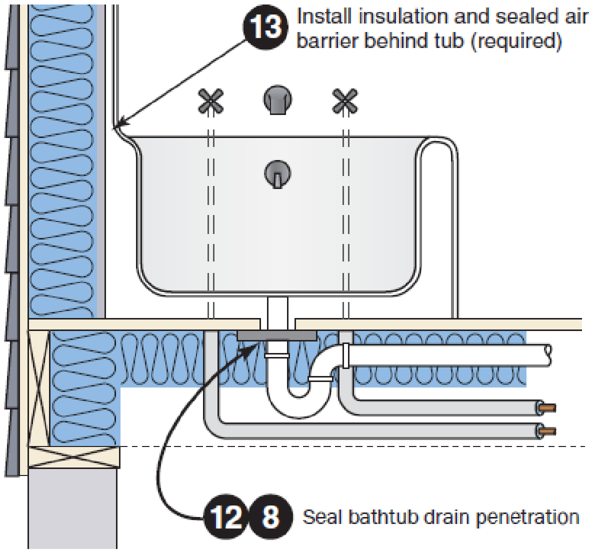

Seal lights and bath vent fans to ceiling drywall
2
8
Fan vented through exterior wall sealed at penetration
11
Seal airtight IC-rated recessed light fixtures to drywall
13
Insulate and install sheet material behind bathtub
3
Insulate headers
3
Insulate corners
Insulated exterior wall
1
12
8
Seal plumbing penetrations (if ceiling is insulated)
4
Window sealed into rough opening using backer rod
FACED BATTS
UNFACED BATTS
SUBFLOOR
Ladder T-wall
Seal gap between electrical box and drywall
12 14
9
Narrow stud cavity batts are cut to fit
3
Caulk
FLOOR JOIST
3
Caulk
14
12
8
12
8
Seal wiring and plumbing penetrations
Electrical panel box, recommend install on interior (non-insulated) wall. If installed on exterior wall, air barrier shall extend behind box or air-sealed box shall be installed.

AIR SEALING


Chases and common by-passes
2
Cap top of chase with solid air barrier and insulate above dropped soffit
Seal chases 8
Install air barrier on interior of all insulated walls
1
Seal top plate
MULTIFAMILY COMMON WALL
1 2
Caulk electrical boxes and fixtures to drywall
INTERIOR WALL
Seal HVAC penetrations
16
14 12
Seal electrical penetrations
Seal plumbing penetrations
Seal bottom plate
3
15 Seal penetrations in common wall
Seal bottom plate
3
16 Seal HVAC boot penetrations

AIR SEALING BLOCKING & SHEATHING

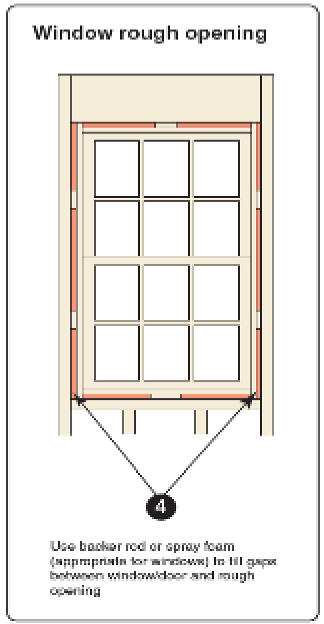
Solid sheet behind tubs & showers on insulated walls

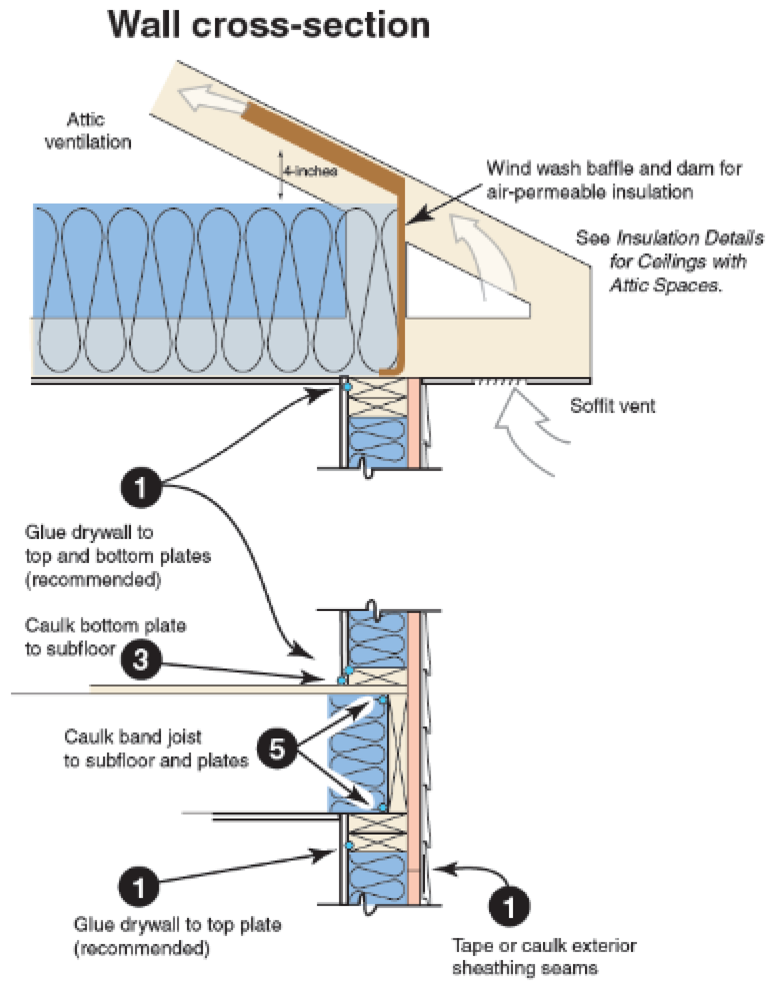


Call back waiting to occur

Call back prevention

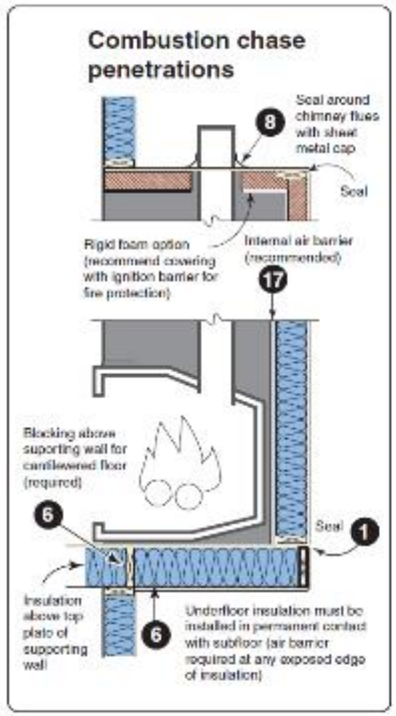
AIR SEALING WINDOWS & WALLS

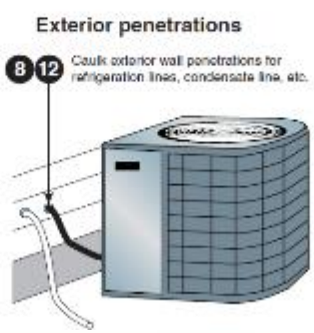


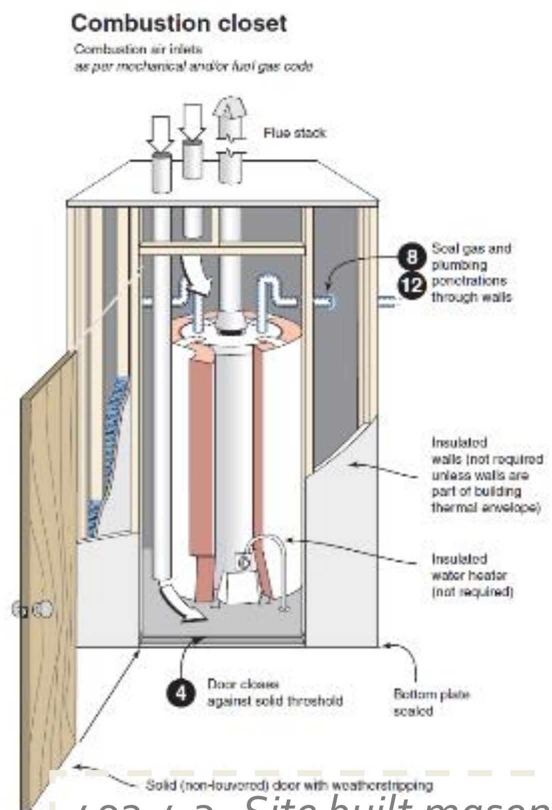


402.4.4- Windows, skylights and doors ≤ 0.3 cfm/s.f.,
Swinging doors ≤ 0.5 cfm/s.f.
Exception: site built

AIR SEALING







402.4.3- *Site built masonry* wood-burning fireplaces must have gasketed doors and outdoor combustion air

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AIR SEALING – CANTILEVERS

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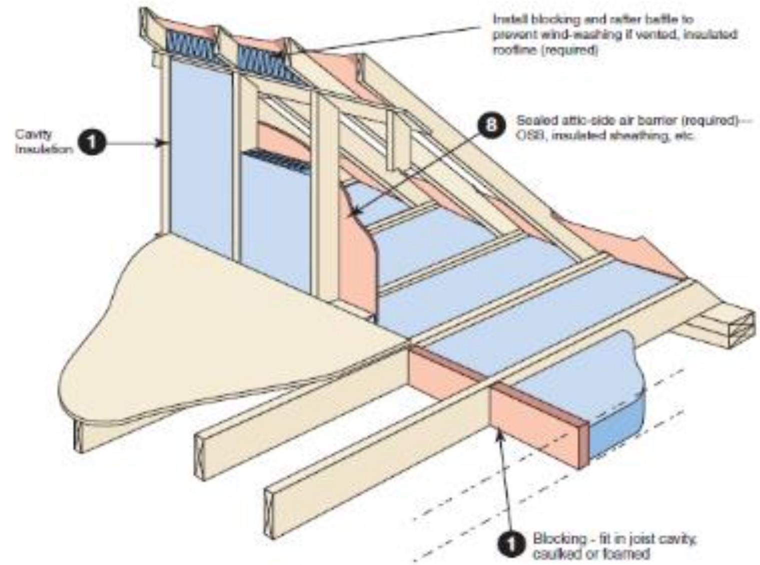
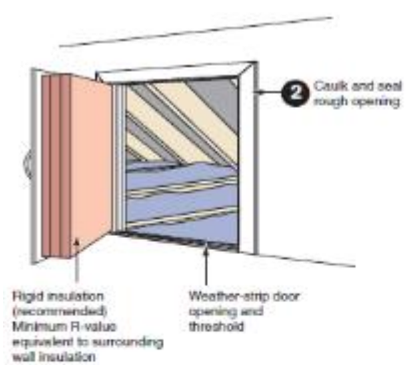
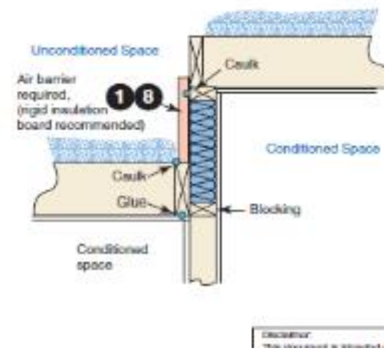
AIR SEALING KNEEWALLS



Attic knee-walls



Two-level attic



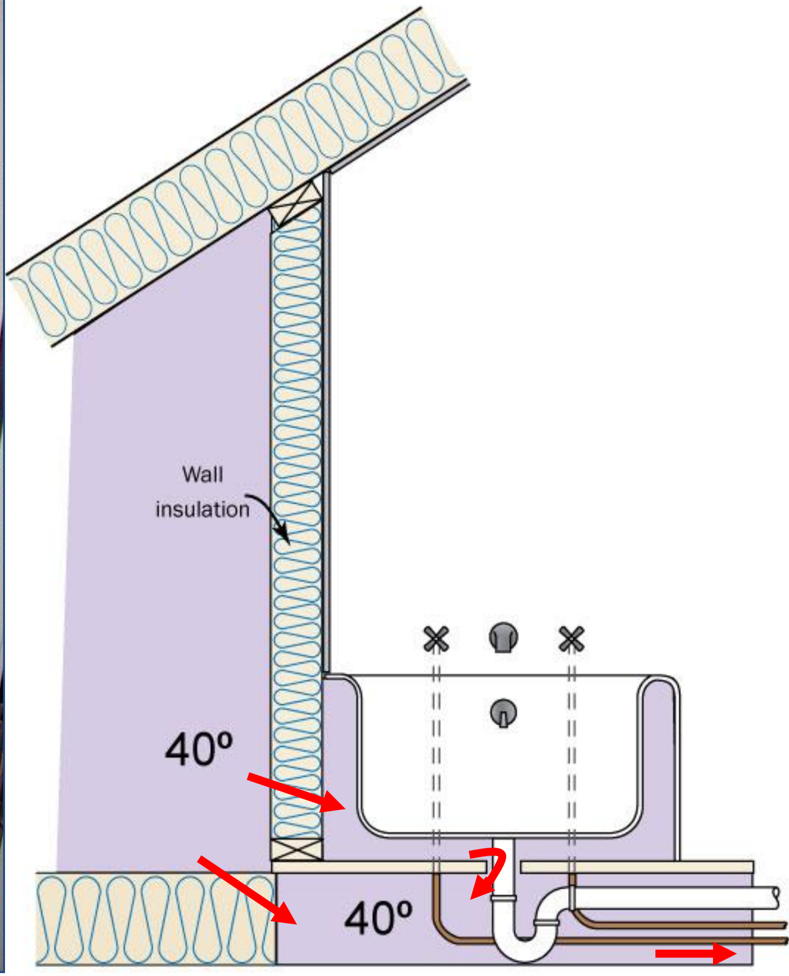
NO BLOCKING UNDER ATTIC KNEEWALLS

NO BLOCKING UNDER ATTIC KNEEWALLS

PROPER BLOCKING @ATTIC KNEEWALLS

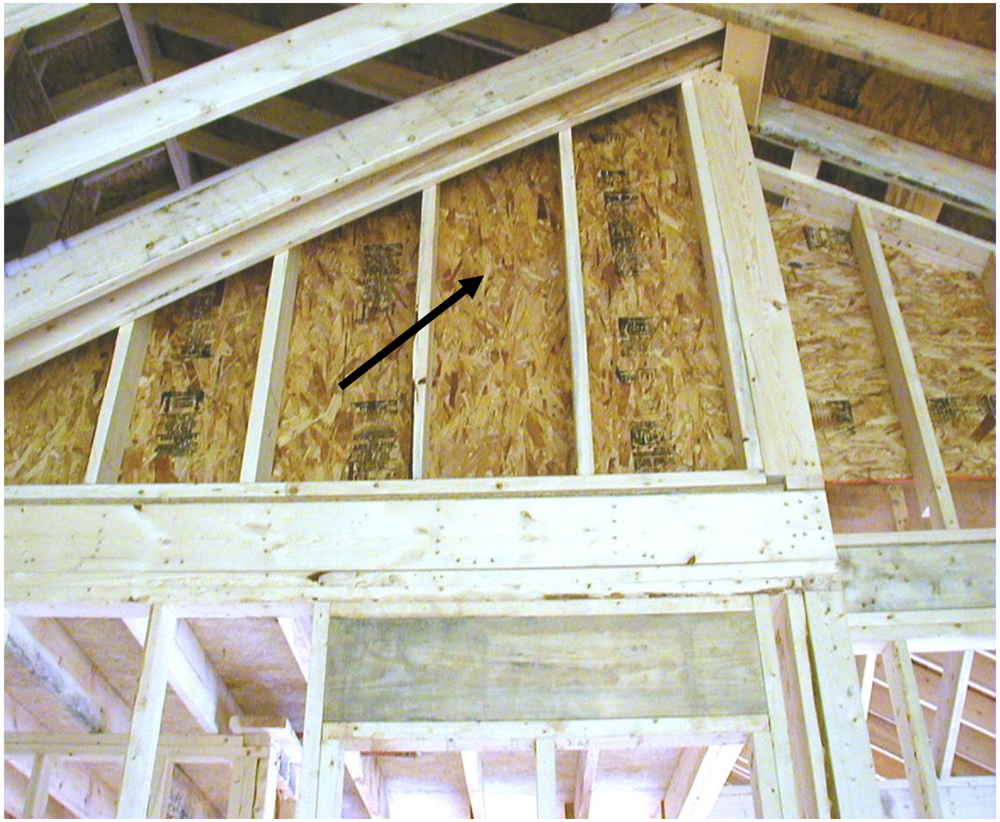
Ineffective Kneewall Insulation

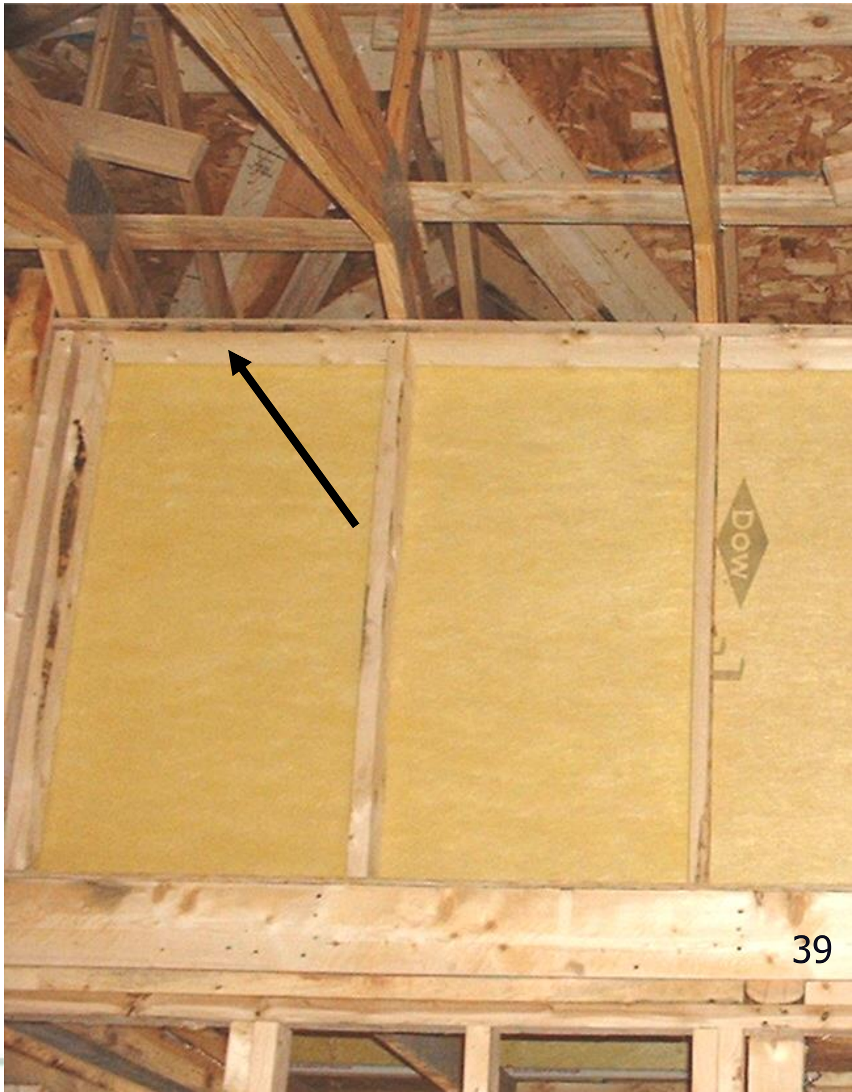
due to lack of continuous contact with air barrier



AIR SEALING BLOCKING & SHEATHING

Attic kneewalls should be sheathed and capped





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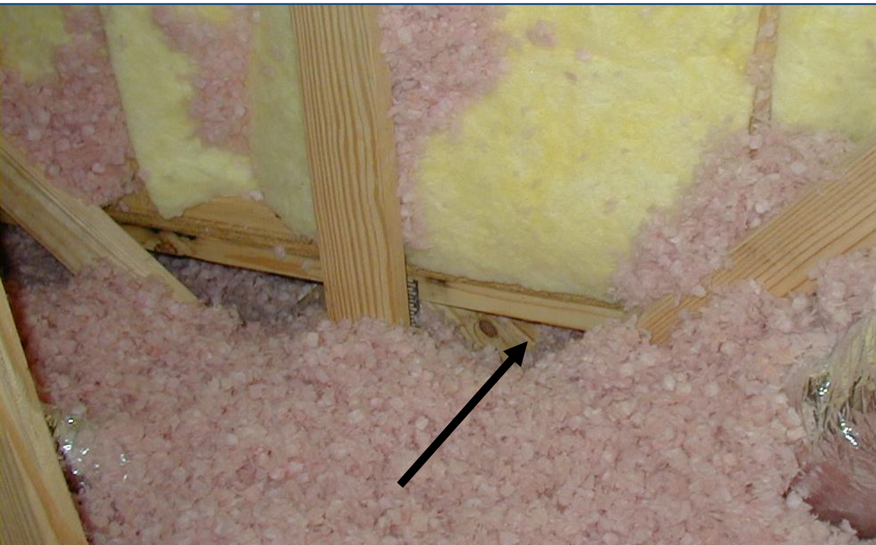
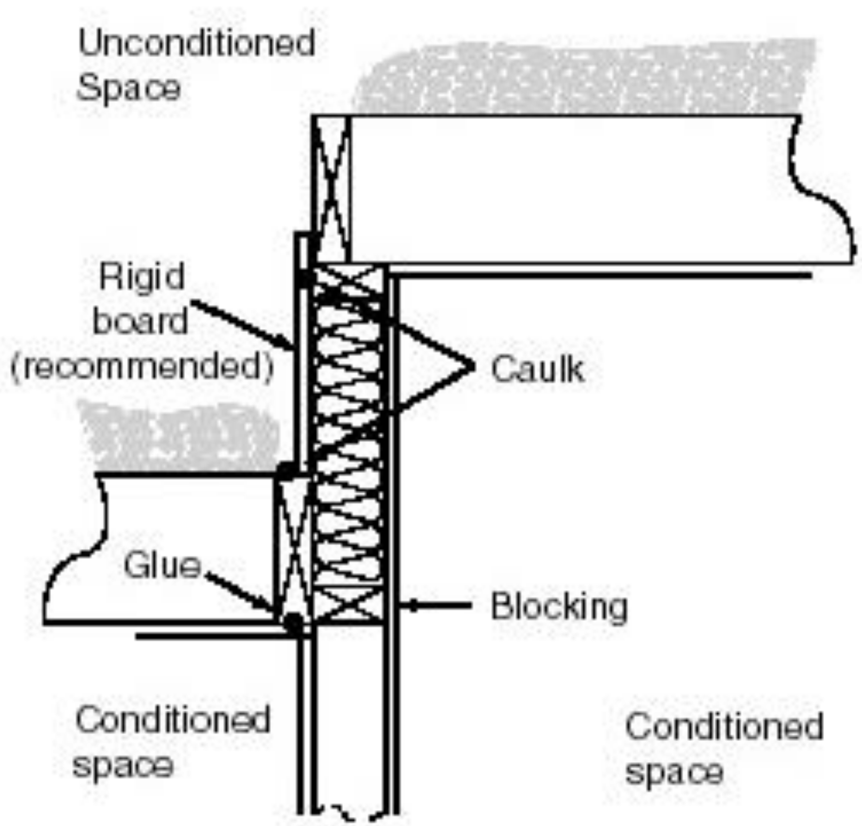
AIR SEALING BLOCKING & SHEATHING

Joist cavities under attic kneewalls must be blocked



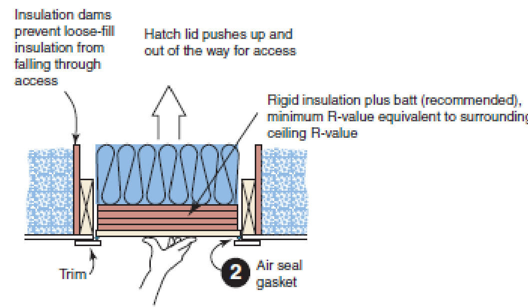
AIR SEALING BLOCKING & SHEATHING

Block stud cavities at changes in ceiling height

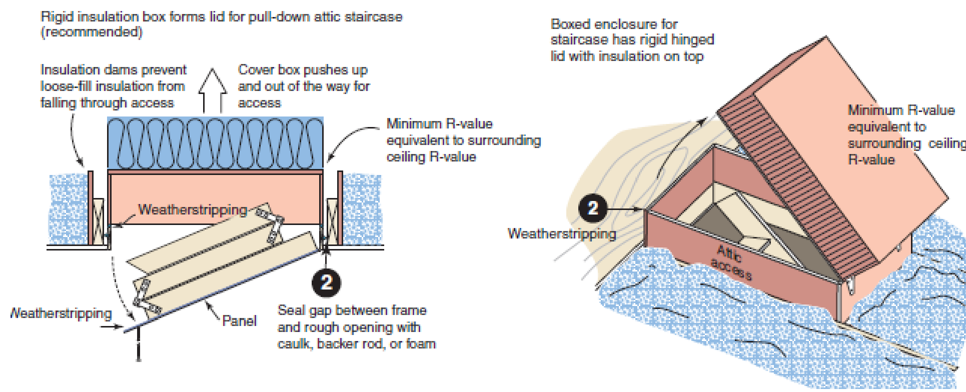


AIR SEALING ATTIC ACCESS

Attic scuttle



Attic pull-down stairs



AIR SEALING ATTIC ACCESS

Attic scuttle holes must seal tight- requires weatherstripping

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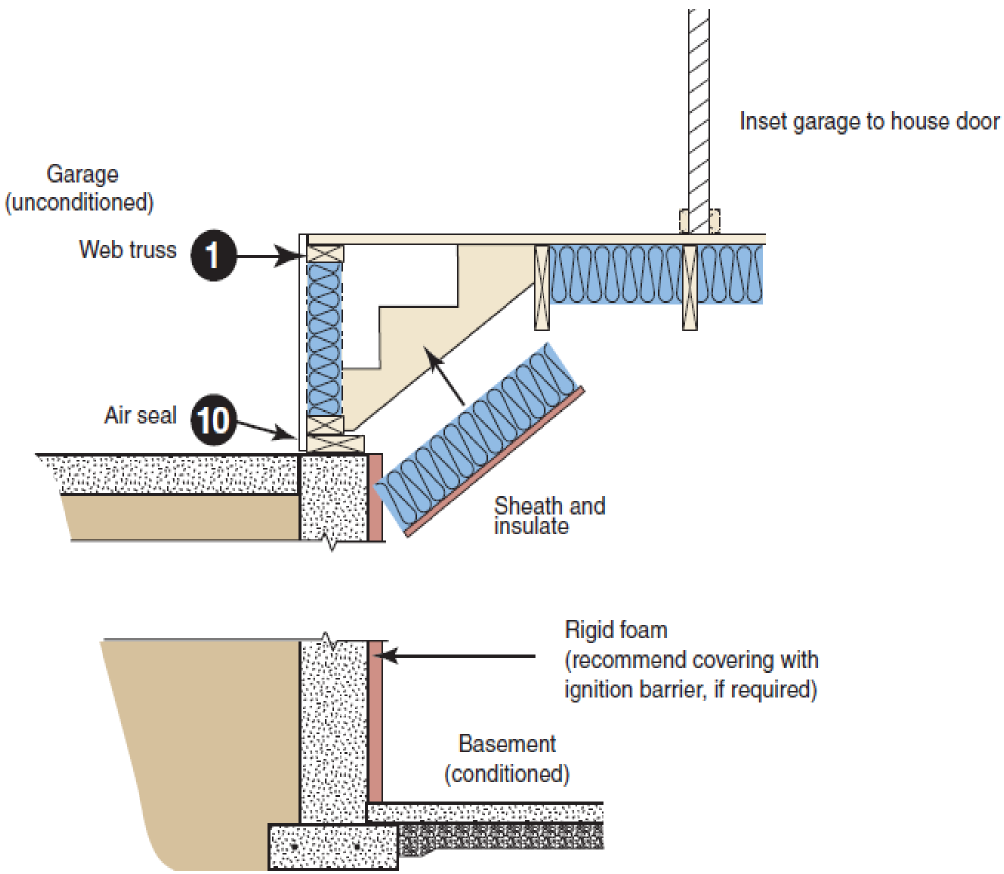
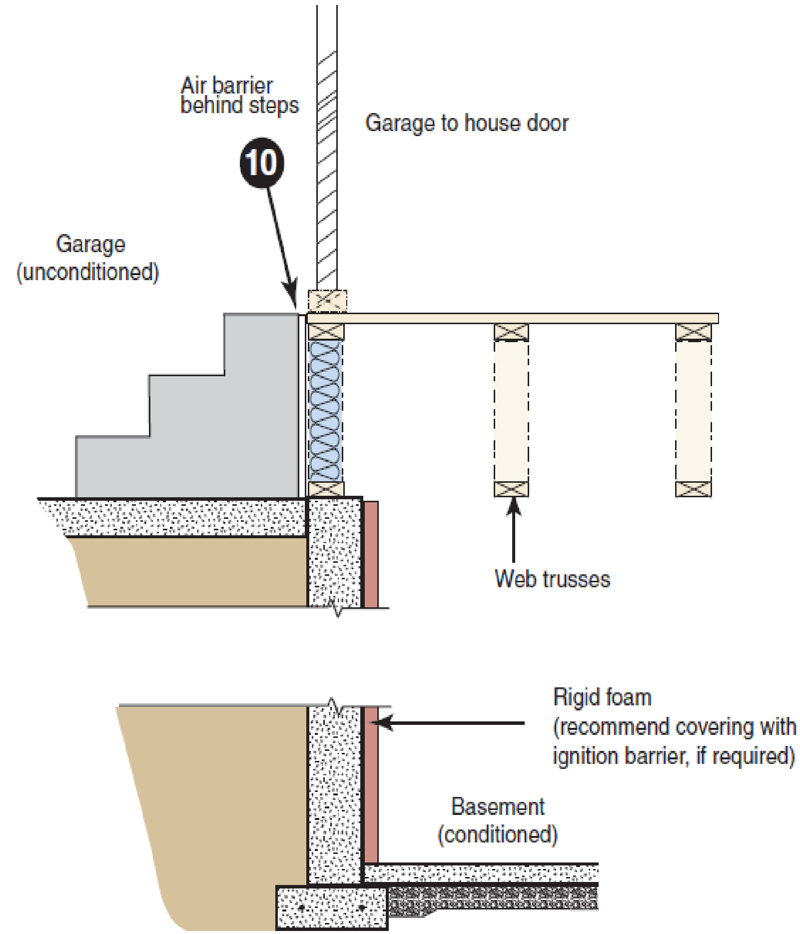
ATTIC ACCESS OPTIONS

AIR SEALING ADJACENT GARAGE





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402.4.5 RECESSED LIGHTS

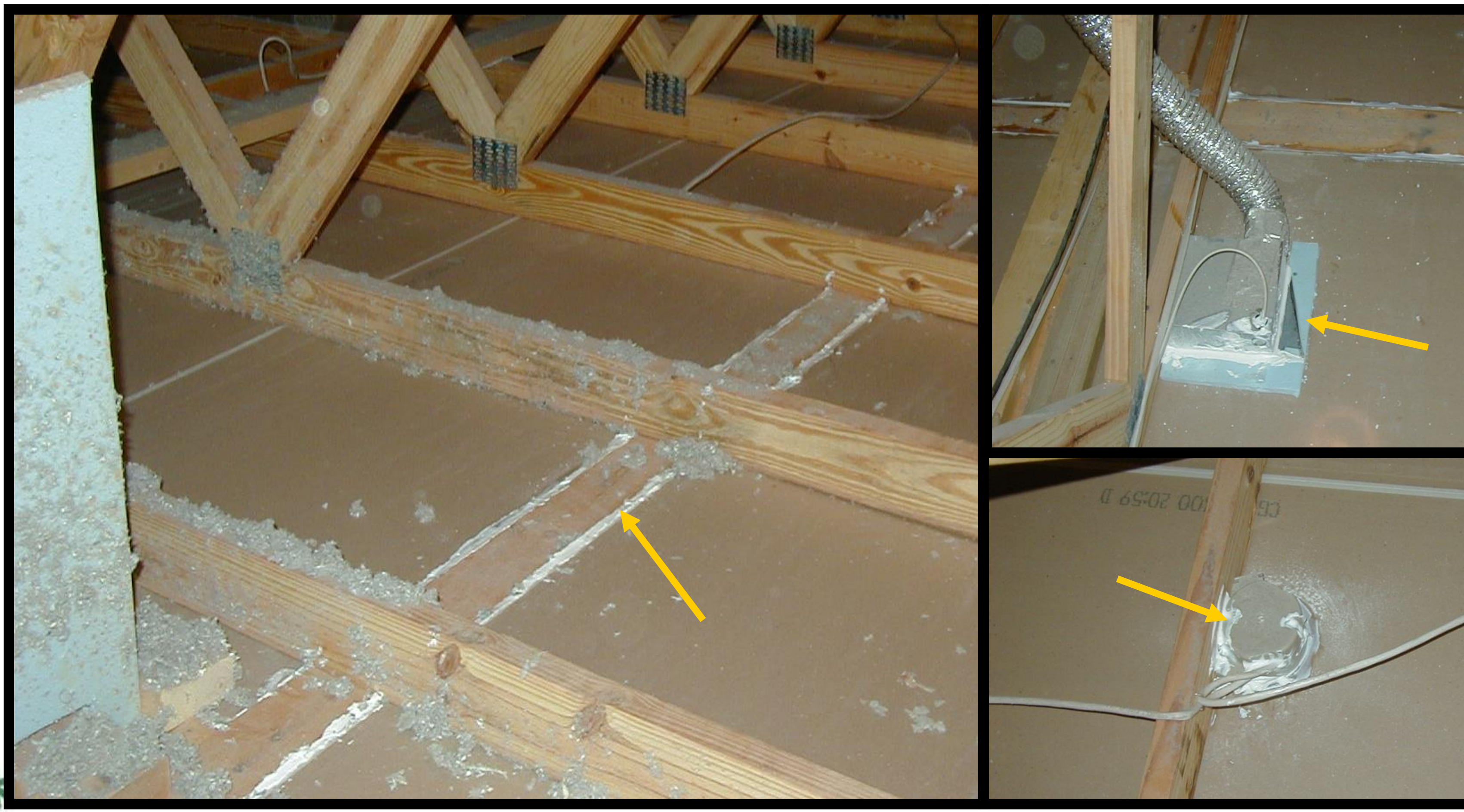
Standard Can Light

Air-tight and IC Rated

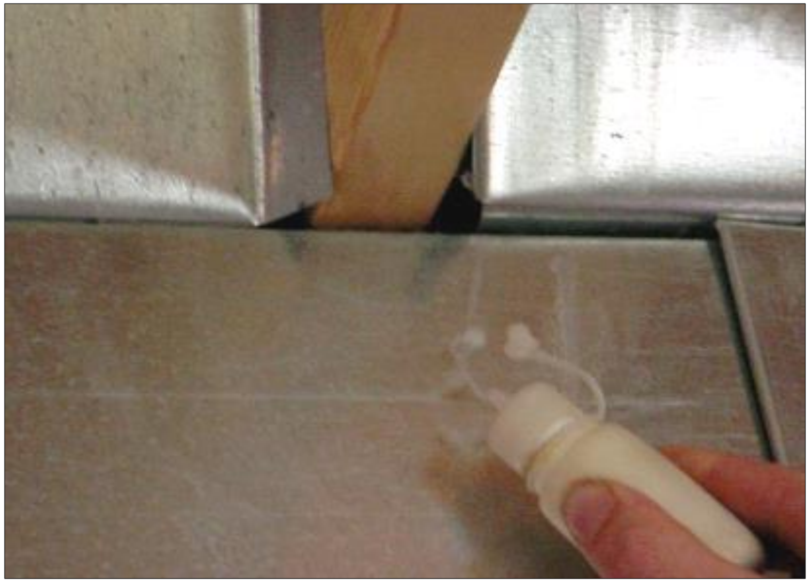
402.4.5 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as meeting ASTM E 283 when tested at 1.57 psf (75 Pa) pressure differential with no more than 2.0 cfm (0.944 L/s) of air movement from the *conditioned space* to the ceiling cavity. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

AIR SEALING AFTER DRYWALL

- Top plate to drywall
  (interior wall cavities often connect to attic)
- HVAC and electrical penetrations

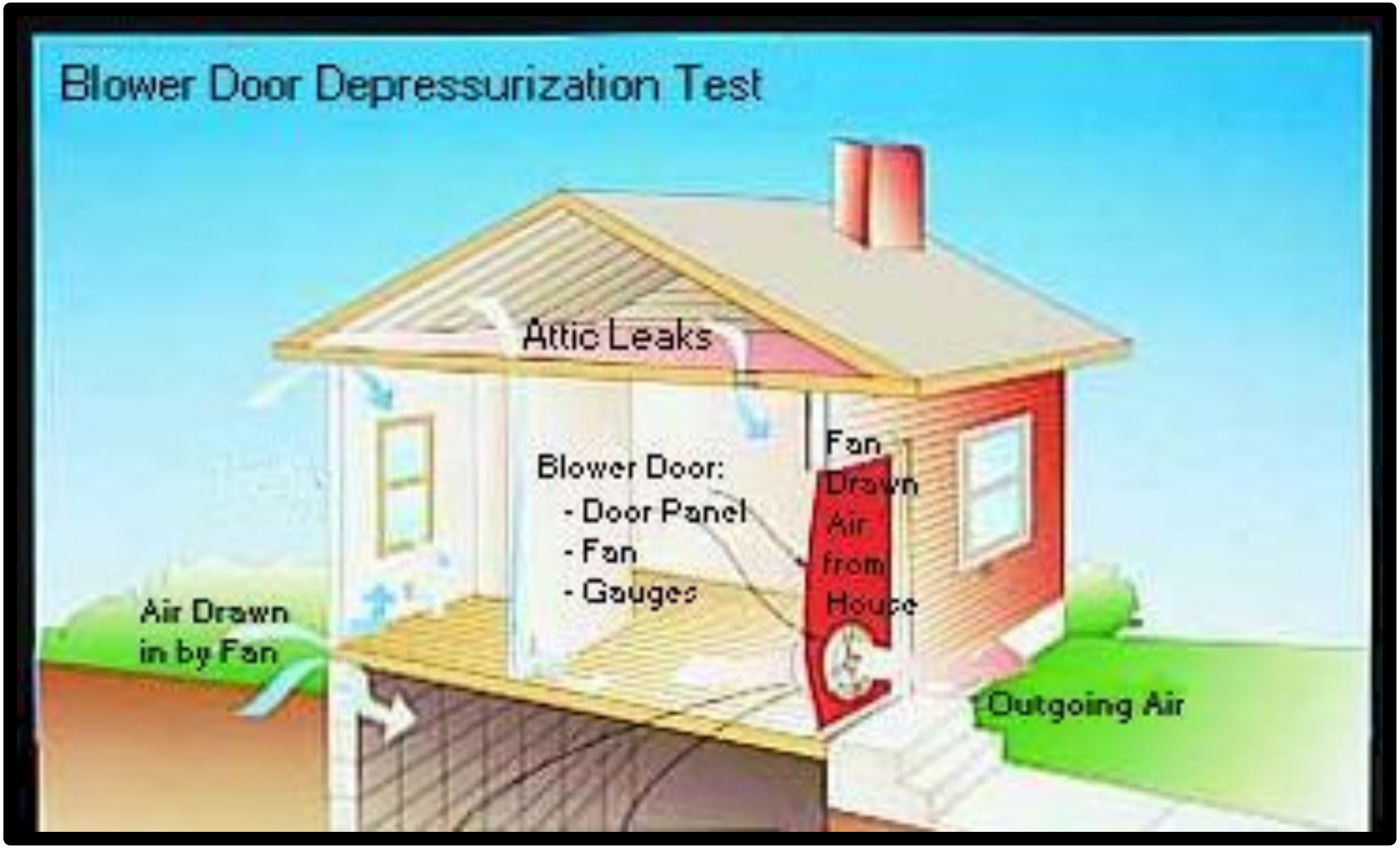


BLOWER DOOR TESTING



- One of the options allowed by code to verify air sealing
- Provides a measurement of the actual infiltration rate
- Code requires < 7 ACH50
- The BD also helps identify leak paths

BLOWER DOOR OPERATION

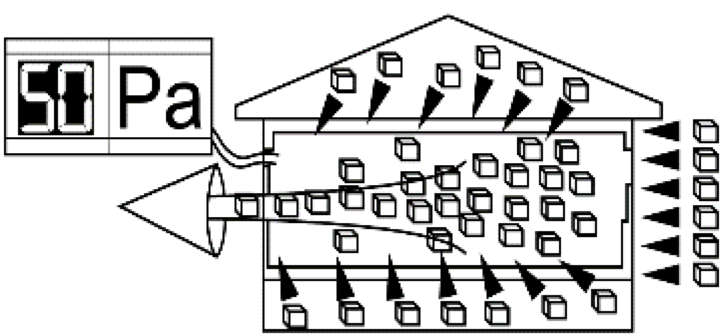


DEPRESSURIZING HOUSE

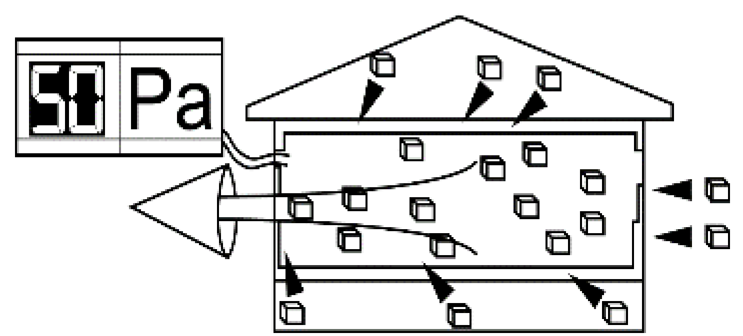
- CFM = Cubic Feet of air per Minute
- 1 CFM out = 1 CFM in
- 1000 CFM_{50} = ~ 1 s.f. hole in envelope

Blower Door Depressurizing House

To 50 Pascals with Respect to Outside



Leaky House



Tight House

PRACTICAL AIR SEALING - EXAMPLES

A home performance crew moved the attic insulation aside to access the gaps at the **top plates**

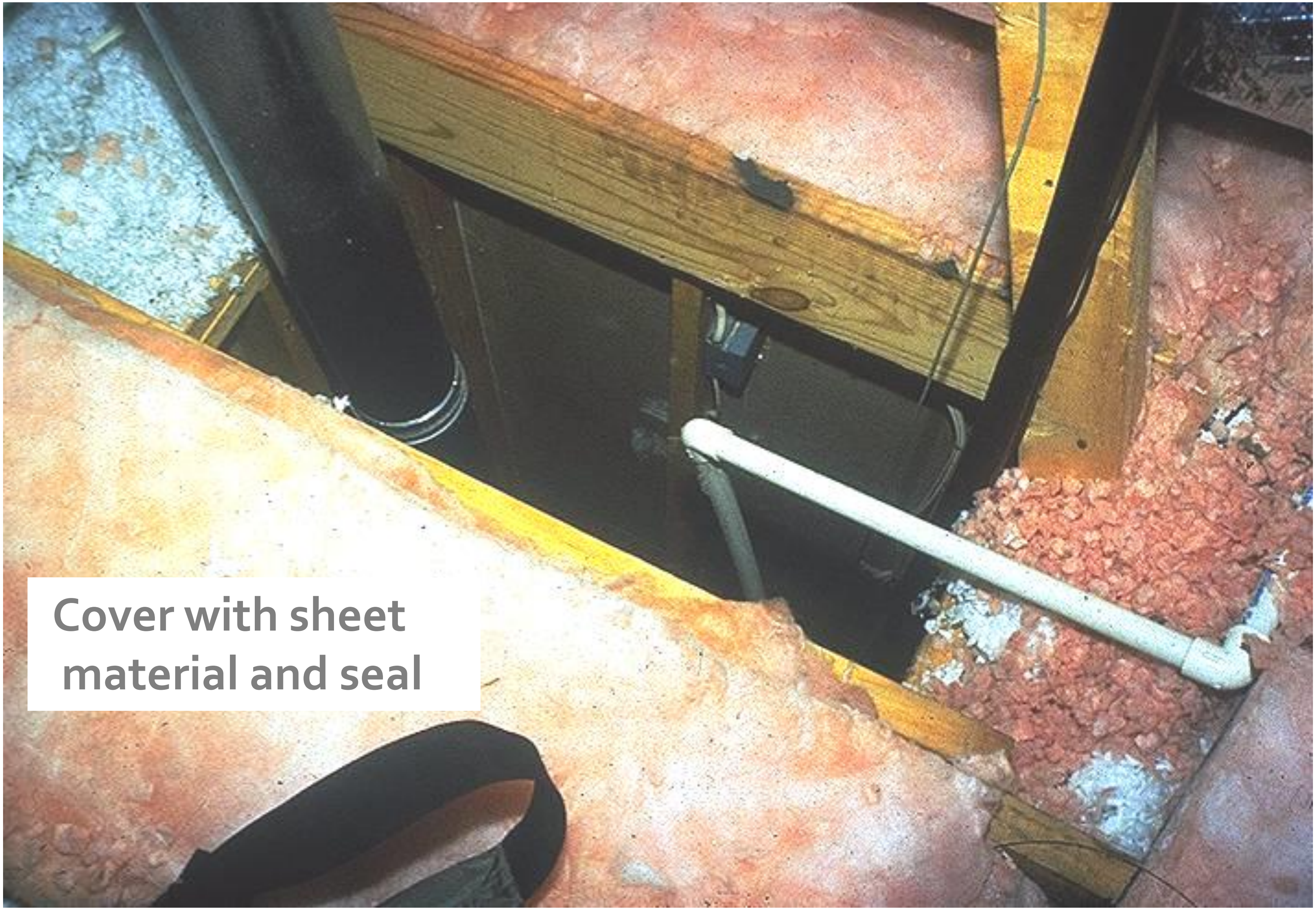
The crew sealed the gaps with **one part foam** and will install insulation on top of the sealed pressure boundary

PRACTICAL AIR SEALING - EXAMPLES

Many homes with attics have large open **chases** (vertical “tunnels” in a building to accommodate air ducts, plumbing and chimneys)

A crew “capped” this chase with rigid foam board and sealed the perimeter with one part foam. They will install insulation on top.

PRACTICAL AIR SEALING - EXAMPLES



COMBUSTION SAFETY

Combustion safety is very important for sealed homes

- Fans have bigger effect on pressures
- Appropriate equipment selection, location & installation is essential
- Safety tests can be performed by qualified individuals

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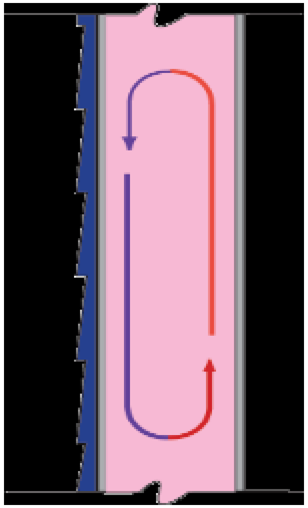
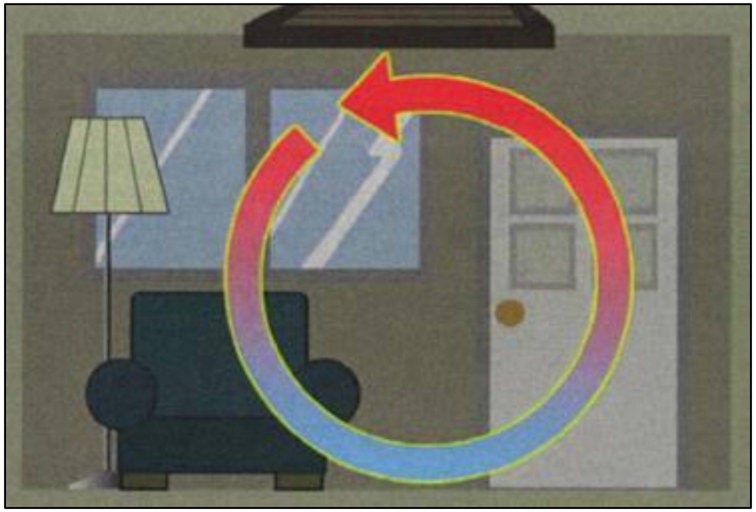
AIR SEALING & INSULATION

- Air sealing & insulation go hand in hand
- Both are necessary for an effective building envelope

CONVECTIVE LOOP

- Air movement due to temperature gradients (temperature is related to pressure)
- Air rises along warm surface and falls along cold surface
- Creates circular movement of air within enclosed space (wall cavity, band between floors, even a room within living space!)
- Transfers heat and can reduce effectiveness of insulation



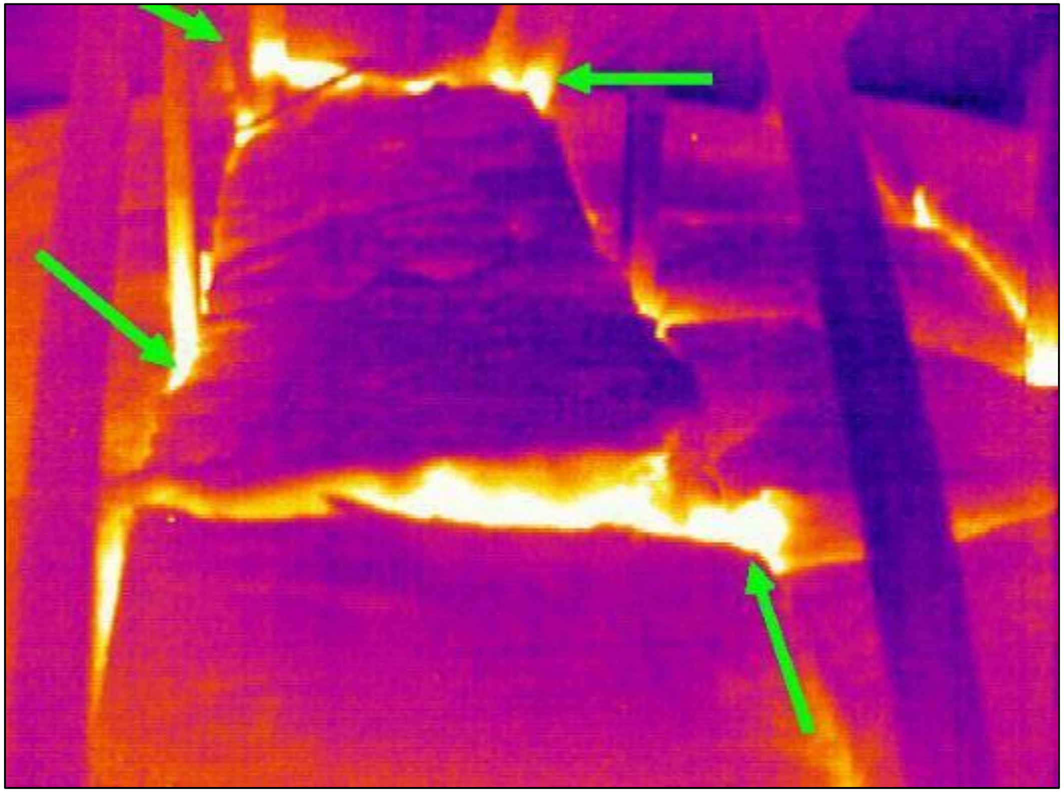


THE IMPORTANCE OF INSULATION

- Energy efficiency
- Comfort
- Durability
- Noise reduction

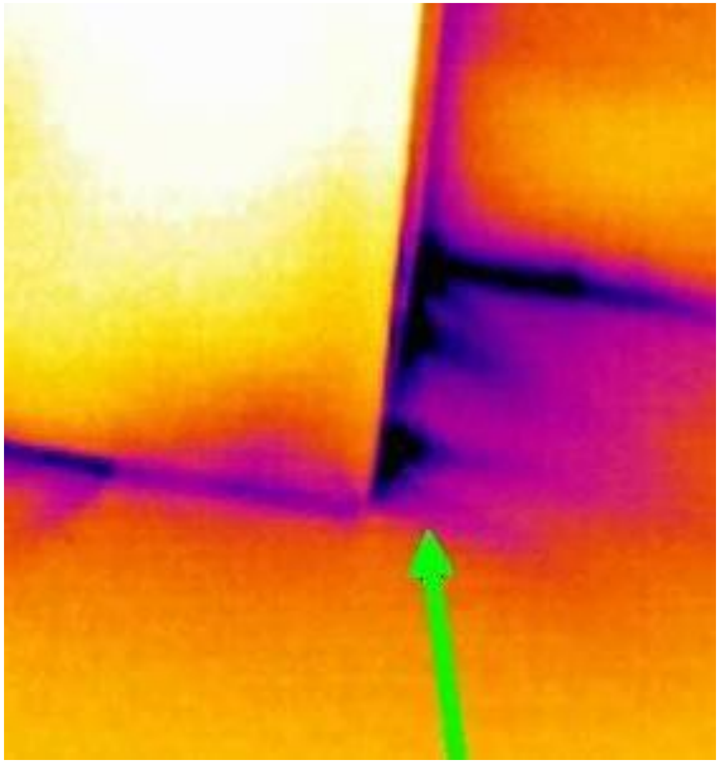
HEAT TRANSFER

- Convection
- Radiation
- Conduction



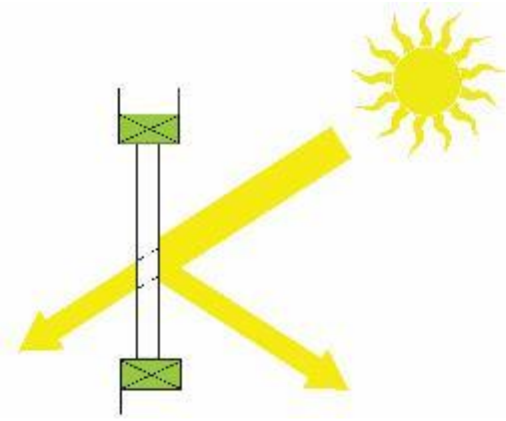
HEAT TRANSFER: CONVECTION

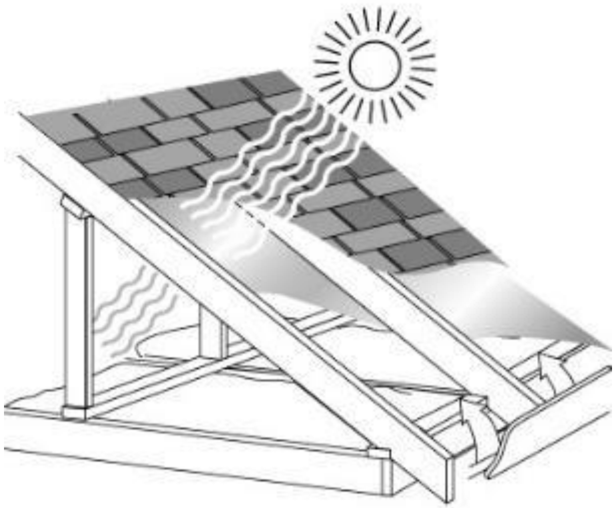
Convection is the transfer of heat caused by the movement of a fluid, like water or air (air barriers slow convection)



HEAT TRANSFER: RADIATION

Radiation is the movement of heat energy from a hot surface to a cooler surface with nothing solid or opaque in between (low-emitting surfaces retard radiation)

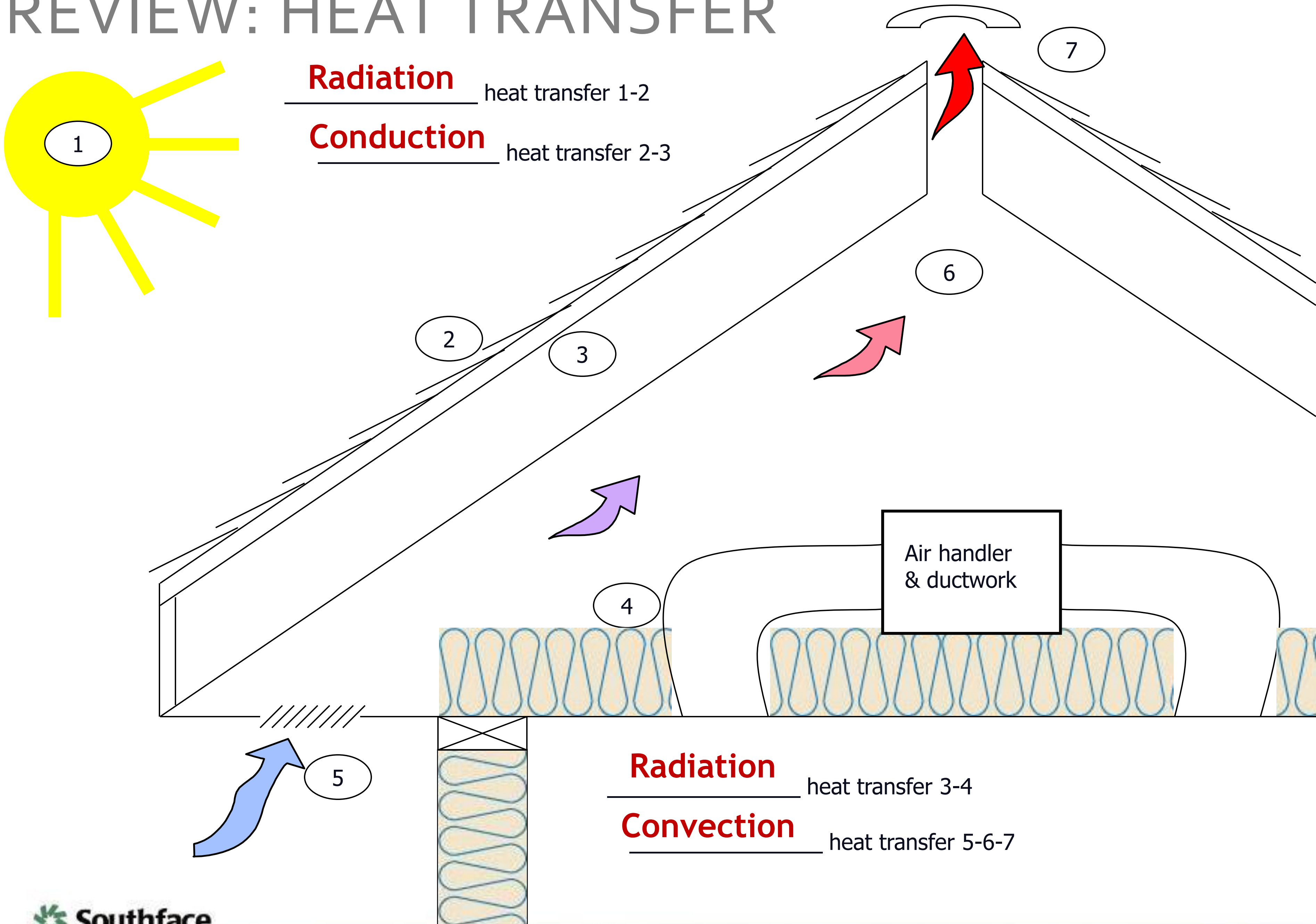




HEAT FLOW: CONDUCTION

Conduction is heat flowing through a solid material (insulation slows conduction)

REVIEW: HEAT TRANSFER



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R-VALUE AND U-FACTOR

- A material's R-value is a measurement of its thermal resistance
  - High R-value = high resistance to heat conduction
  - Opaque building materials, such as insulation and sheathing, are given R-value ratings

- U-factor measures the rate of heat transfer across a material's surface
  - Low U-factor = better ability to resist heat conduction
  - Windows are rated in U-factor

- Simply put, U-factor is the inverse of R-value
  - $U = \frac{1}{R}$ and $R = \frac{1}{U}$

CONDUCTIVE HEAT TRANSFER

The rate of heat transfer across a solid object is dependent upon the size of the object (area), the level of insulation (R-value or U-factor) and the difference in temperature on either side of it (ΔT).

$$q = \frac{A\ x\ \Delta T}{R}$$

q = heat flow (Btu/hr)

A = area (square feet)

ΔT = temperature difference across component (°F)

R = R-value of insulation

$$q = A\ x\ \Delta T\ x\ U$$

q = heat flow (Btu/hr)

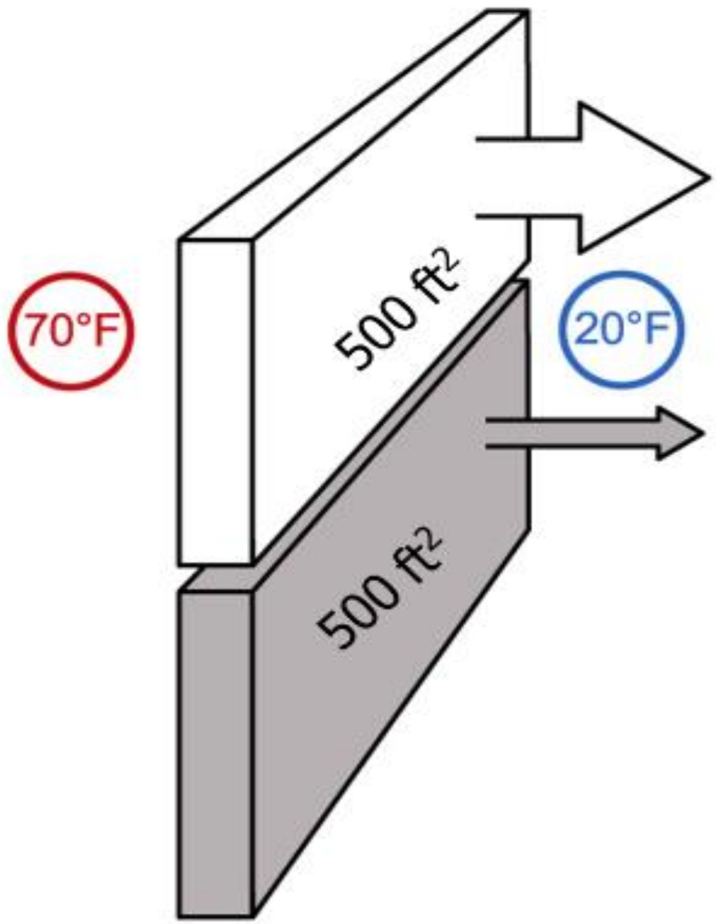
A = area (square feet)

ΔT = temperature difference across component (°F)

U = U-factor of the assembly

CONDUCTIVE HEAT TRANSFER

$q = U \times A \times \Delta T$



Use the formula on the previous slide to determine the conduction loss through the wall with the given values.

Low R-value (R-5) = ___________

High R-value (R-10) = __

Total = _______

CONDUCTIVE HEAT TRANSFER

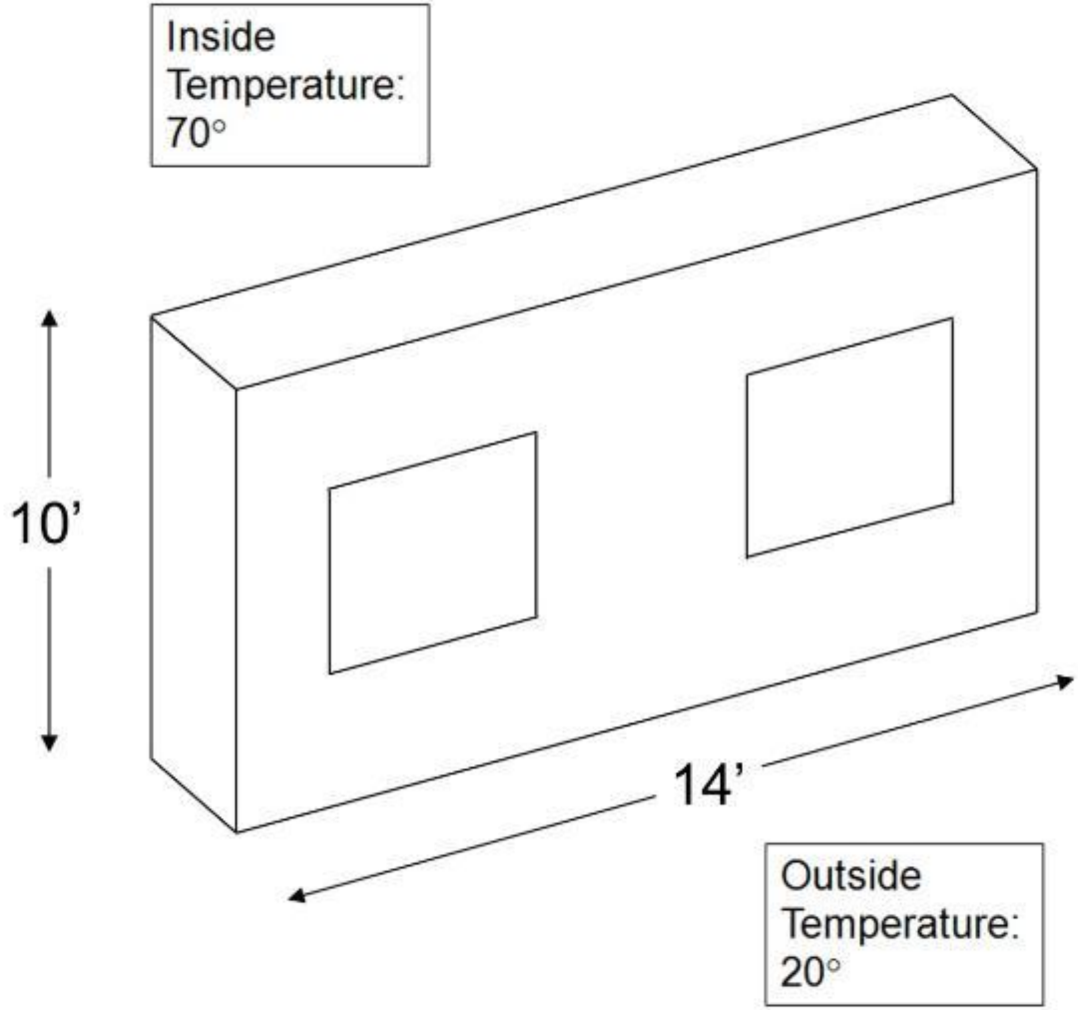
Windows:

each 4'x6'

U = 0.35

Walls (opaque):

R-13

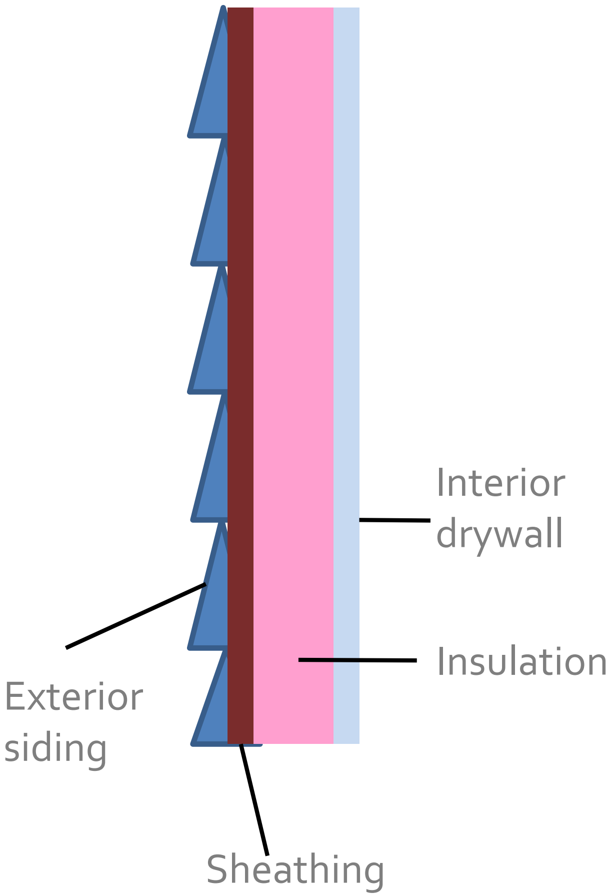


R-VALUE AND U-FACTOR

Important to remember:

- R-values of materials that are stacked together may be added together to determine a total R-value of the assembly
- U-factors cannot be added together in the same way
- R-values cannot be averaged together but U-factors can be averaged

DETERMINING TOTAL R-VALUE



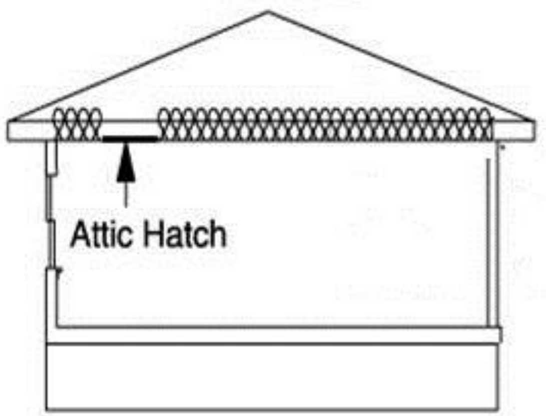
Example:
Exterior siding: R-0.4
Sheathing: R-1
Insulation: R-13
Interior drywall: R-0.5

R-values of differing materials stacked together in an assembly may be added together to determine a total R-value

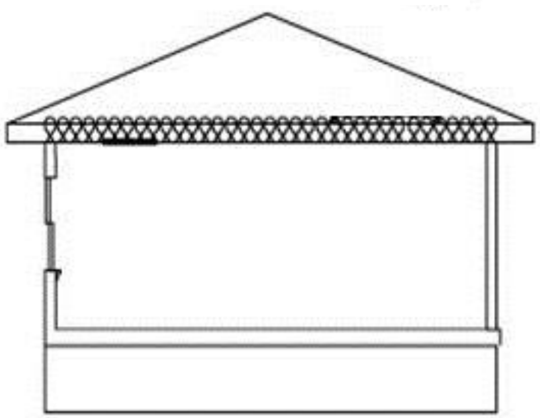
Solution:
0.4 + 1 + 13 + 0.5 = R-14.9

COVERAGE IS KEY! AVERAGE R-VALUE

"R-38 Attic"



R-28 – Full Coverage



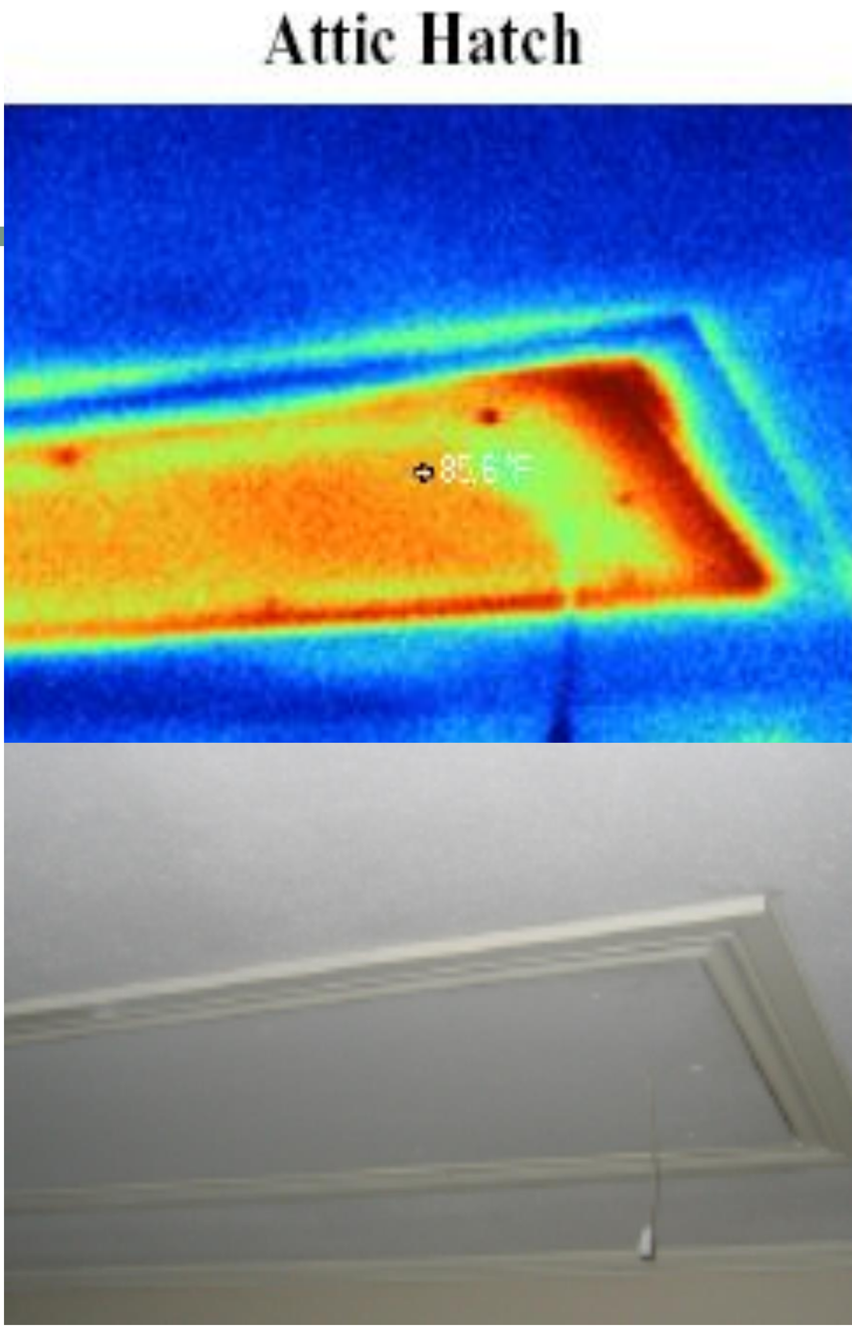
Remember, R-values cannot be averaged, but U-factors can be

$$U_{avg} = \frac{U_1 \times A_1 + U_2 \times A_2}{A_{Total}}$$

Example Problem:

An attic has a total area of 1000 ft². If 990 ft² is installed with R-38 while 10 ft² is an uninsulated attic access (R-1), what is the average R-value of the total attic space?

INSTALLING INSULATION COVERAGE IS KEY!



1000 s.f of Attic

990 s.f. is R-38

10 s.f. is R-1

IS INSULATION AN AIR BARRIER?

Insulation is not an air barrier!*

*Except…

- Spray foam
- ~~Dense pack cellulose (3.5 lb/cu.ft.)~~
- Rigid foam board (sealed seams)

2009 IECC PRESCRIPTIVE REQUIREMENTS

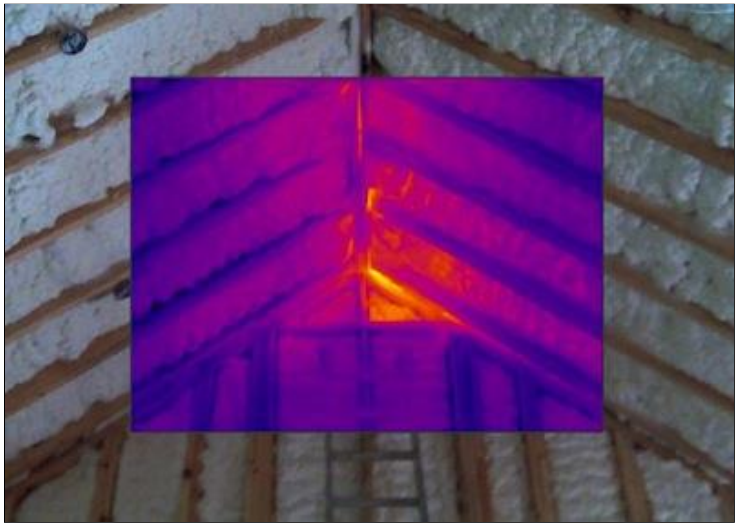
TABLE 402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

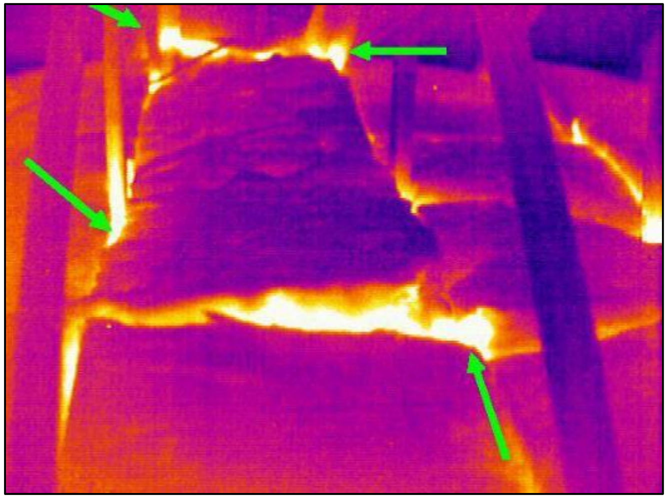
CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	1.2	0.75	0.30	30	13	3/4	13	0	0	0
2	0.65[j]	0.75	0.30	30	13	4/6	13	0	0	0
3	0.50[j]	0.65	0.30	30	13	5/8	19	5/13[f]	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.35	0.60	NR	38	20 or 13+5[h]	13/17	30[g]	10/13	10, 2 ft	10/13
6	0.35	0.60	NR	49	20 or 13+5[h]	15/19	30[g]	15/19	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19/21	38[g]	15/19	10, 4 ft	10/13

2009 IECC Insulation and window efficiencies table

INSTALLATION

- It is possible to meet code and achieve effective results with a variety of products:
  - Fiberglass batts
  - Loose fill
  - Dense pack
  - Rigid board
  - Spray foam
- Regardless of type, all insulation must be properly installed to be effective!





EXAMPLES OF INSULATION

Kraft-faced fiberglass batt insulation

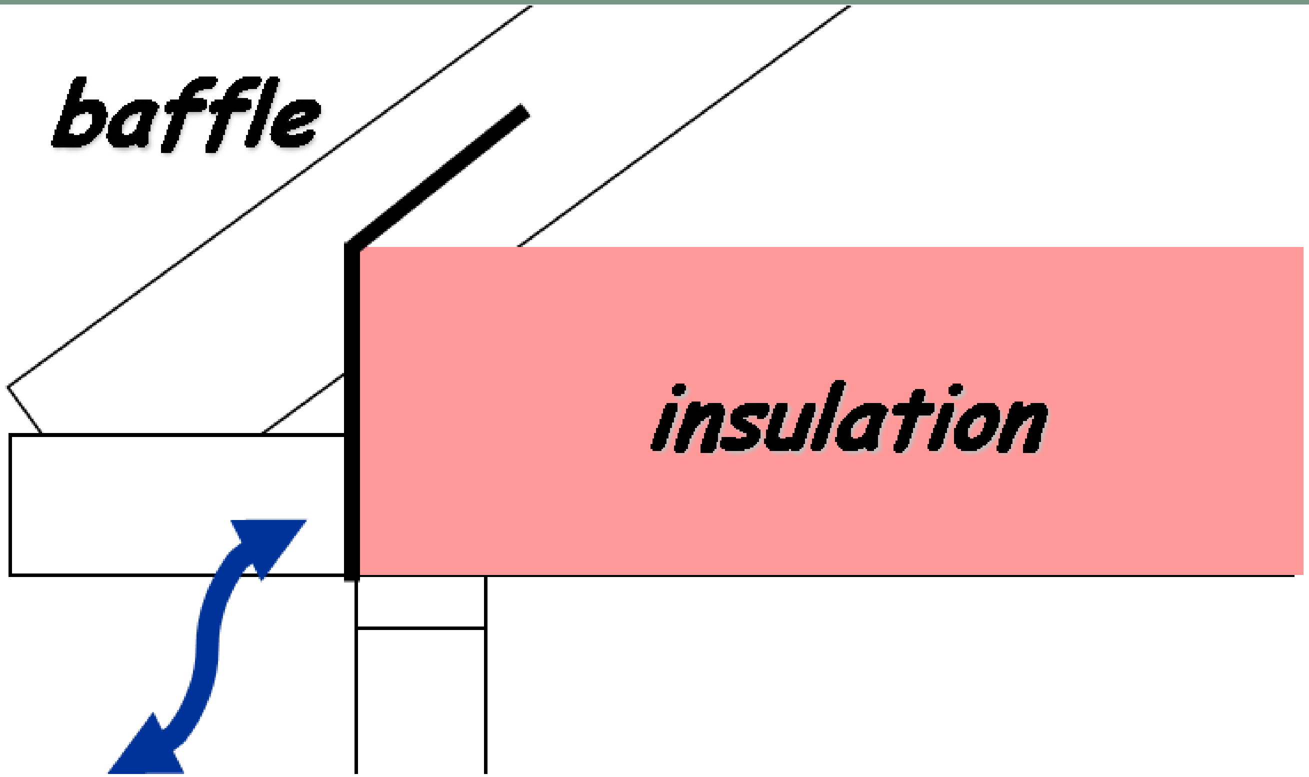
EXAMPLES OF INSULATION

Loose fill insulation (typically fiberglass or cellulose)

CEILING INSULATION

- Rulers and attic card in each attic space
- Blown insulation should not block soffit vents – use baffles

INSULATION: BAFFLES



- Protects insulation from wind-wash
- Ensures proper ventilation by preventing insulation from blocking soffit vent

EXAMPLES OF INSULATION

Spray-applied foam

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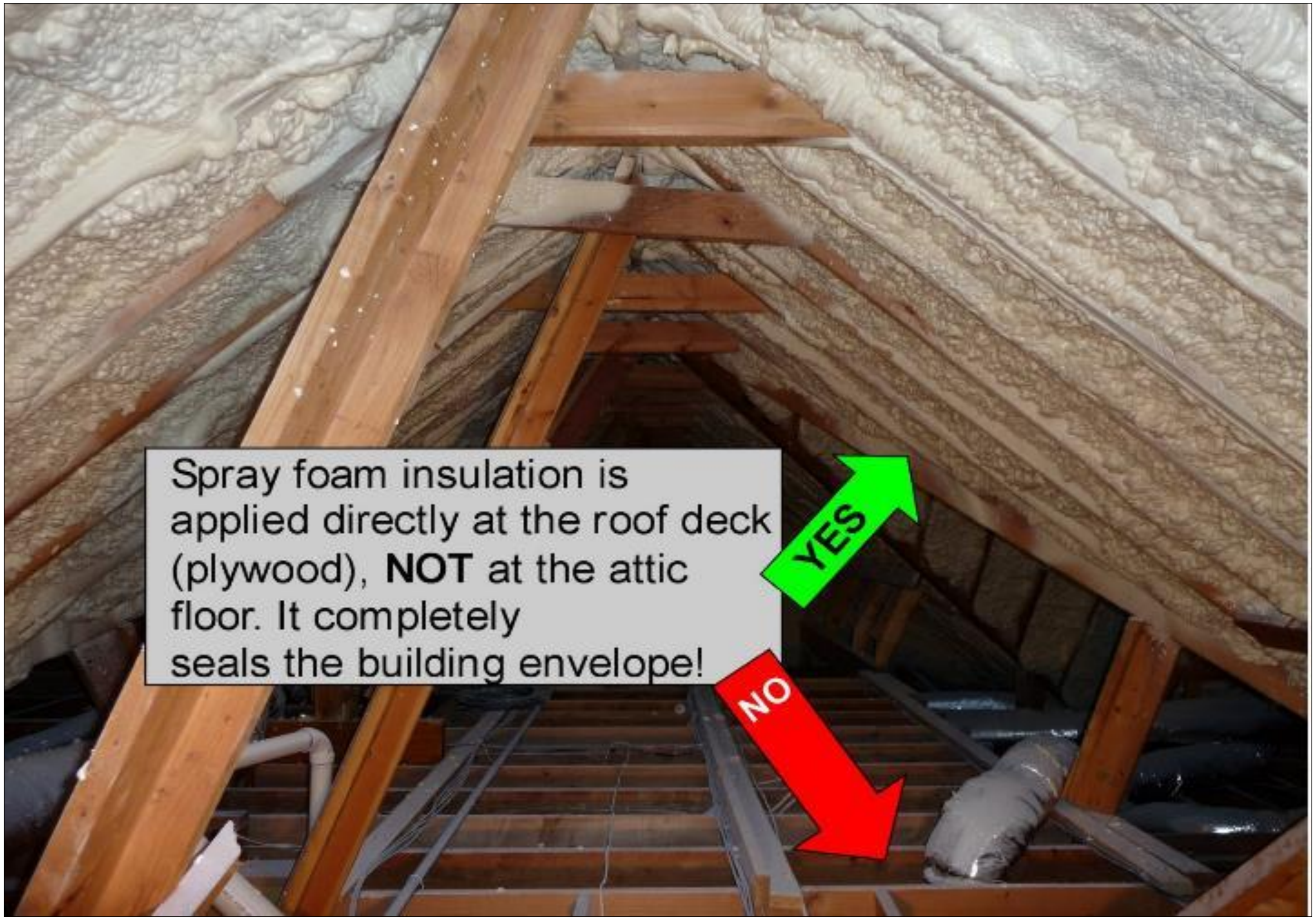
EXAMPLES OF INSULATION



R-VALUES OF INSULATION

Typical Insulation R-values

Insulation Type	R-value per inch	Typical Applications
Cellulose, loose fill	3.7	Attic Floor
Cellulose, high density	3.2	Walls, Enclosed Cavities, Framing Transitions
Fiberglass, batts	3.0*	Basement Ceiling, Open Stud Walls, Attic Floor*
Fiberglass, loose fill	2.8	Attic Floor, Walls (existing)
Fiberglass, loose fill, fluffed below manufacturer's standards	uncertain	Do not install, or correct by blowing over with higher density
Rockwool	3.0	Attic Floor, Walls, Basement Ceiling (may be loose or batts)
Vermiculite	2.7	Attic Floor
Poly-isocyanurate, rigid board	7.0	Foundation Walls, Attic Access Doors
Polystyrene, expanded rigid board	4.0	Foundation Walls, Sill Plate
Polystyrene, extruded rigid board	5.0	Foundation Walls, Sub-Slab, Sill Plate
Low Density Urethane, sprayed foam	3.7	Attics, Walls (new construction); Sill Plate, Band Joist, Framing Transitions
Urethane, sprayed foam	6.0	Attics, Walls (new construction); Sill Plate, Band Joist, Framing Transitions
Urea Formaldehyde Foam	4.0	Attics, Walls (existing)

FLOOR INSULATION

Rare Problems with Floor Insulation?

INSULATING IN CRAWLSPACES

By choosing where to locate your air-sealing and insulation you can include or exclude the crawlspace from the building envelope

Closed (encapsulated) crawlspace:
Insulate & air seal crawlspace **walls**

Open (vented) crawlspace:
Insulate & air seal **subfloor** above

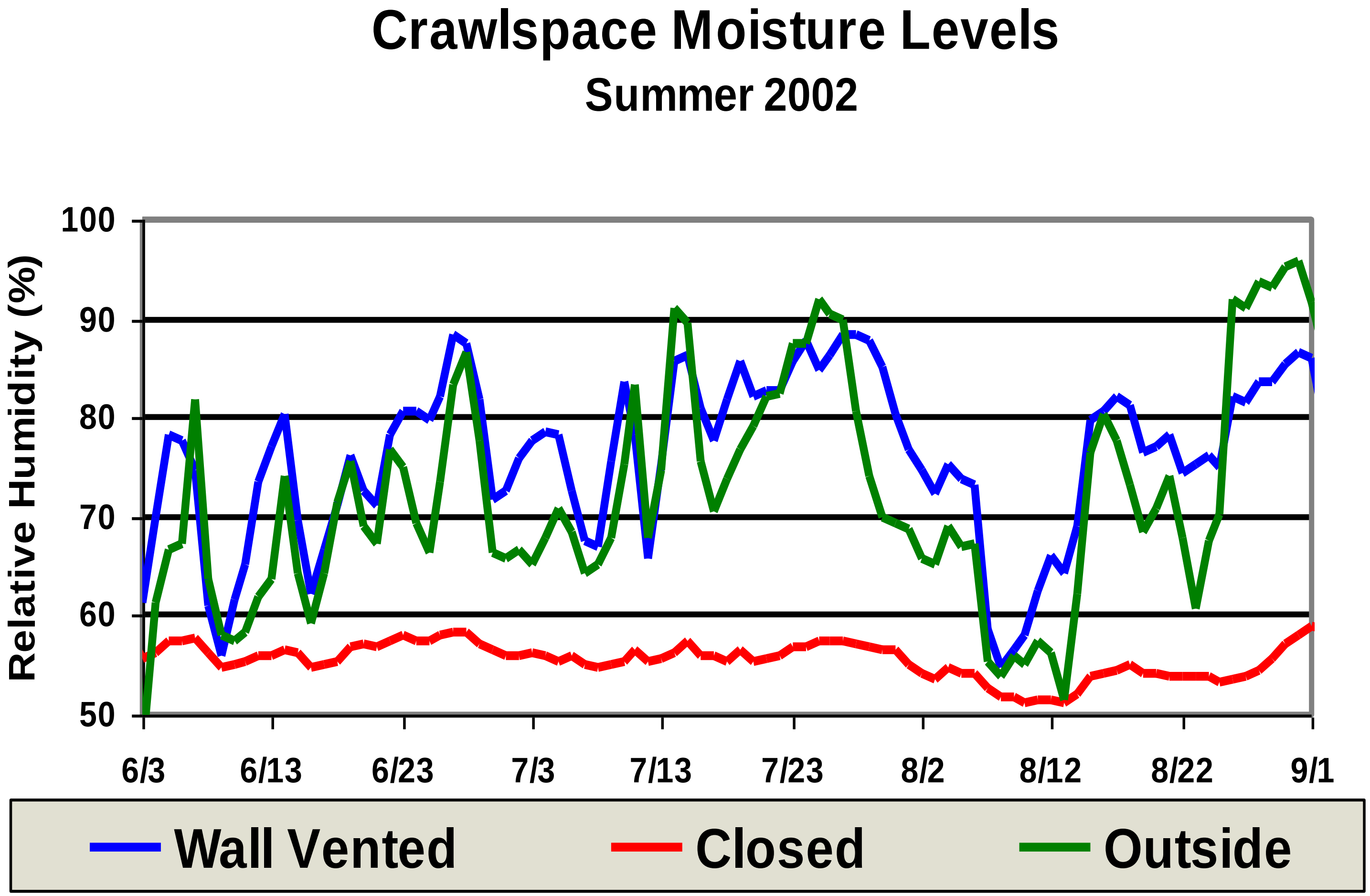
CONTROL MOISTURE!

Whether open or closed, a vapor barrier must be installed!

- Completely seal ground with plastic

  (recommend >6 mil reinforced)
- Overlap seams at least 6”
- Seal all seams and foundation attachment points
- Seal plastic to foundation walls at least 6” above grade

SEALED CRAWLSPACE STUDY



Advanced Energy - crawlspaces.org

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CODE SAYS TO VENT, BUT OFFERS AN EXCEPTION…

SECTION R408
UNDER-FLOOR SPACE

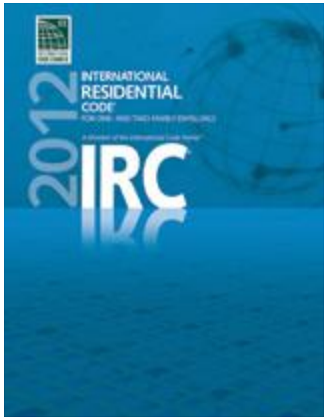
R408.1 Ventilation. The under-floor space between the bottom of the floor joists and the earth under any building (except space occupied by a *basement*) shall have ventilation openings through foundation walls or exterior walls. The minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m^2) for each 150 square feet (14 m^2) of under-floor space area, unless the ground surface is covered by a Class 1 vapor retarder material. When a Class 1 vapor retarder material is used, the minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m^2) for each 1,500 square feet (140 m^2) of under-floor space area. One such ventilating opening shall be within 3 feet (914 mm) of each corner of the building.

R408.2 Openings for under-floor ventilation. The minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m^2) for each 150 square feet (14 m^2) of under-floor area. One ventilation opening shall be within 3 feet (915 mm) of each corner of the building. Ventilation openings shall be covered for their height and width with any of the following materials provided that the least dimension of the covering shall not exceed $^1/_4$ inch (6.4 mm):

1. Perforated sheet metal plates not less than 0.070 inch (1.8 mm) thick.
2. Expanded sheet metal plates not less than 0.047 inch (1.2 mm) thick.
3. Cast-iron grill or grating.
4. Extruded load-bearing brick vents.
5. Hardware cloth of 0.035 inch (0.89 mm) wire or heavier.
6. Corrosion-resistant wire mesh, with the least dimension being $^1/_8$ inch (3.2 mm) thick.

- 1:150 s.f. just vents

1:1500 s.f. with Class I vapor retarder installed
(e.g., 6 mil poly)



UNVENTED OPTION, PART 1

R408.3 Unvented crawl space. Ventilation openings in under-floor spaces specified in Sections R408.1 and R408.2 shall not be required where:

1. Exposed earth is covered with a continuous Class I vapor retarder. Joints of the vapor retarder shall overlap by 6 inches (152 mm) and shall be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall or insulation; and

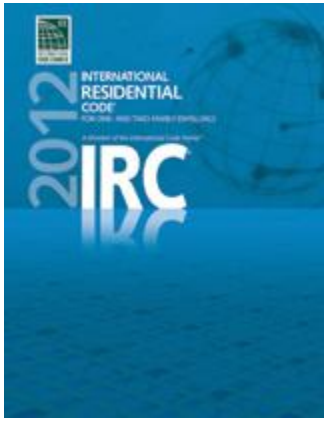
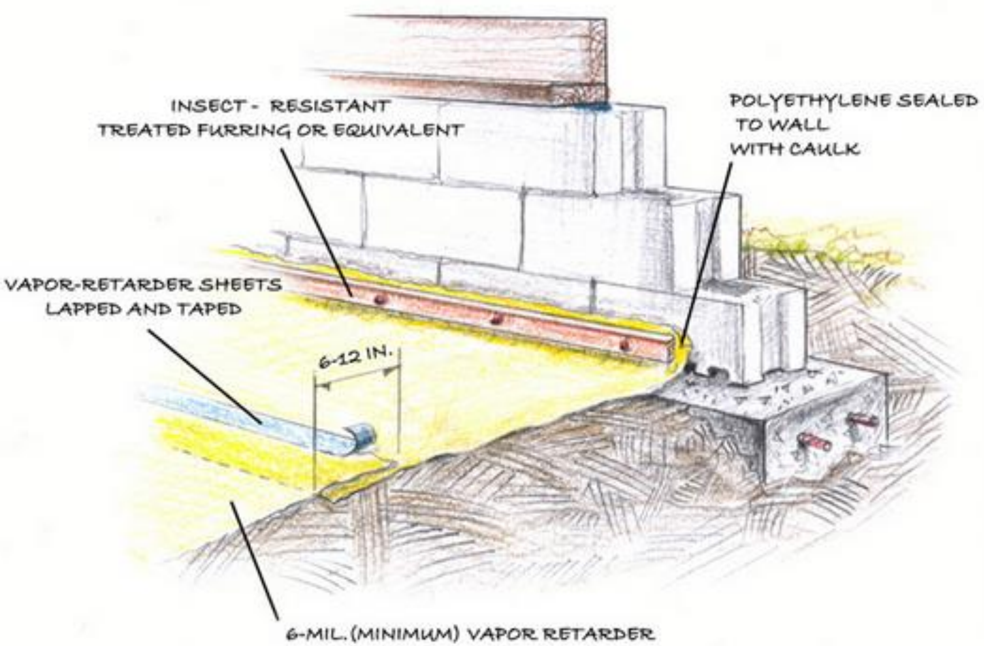


Photo thanks to Donnie Holmes

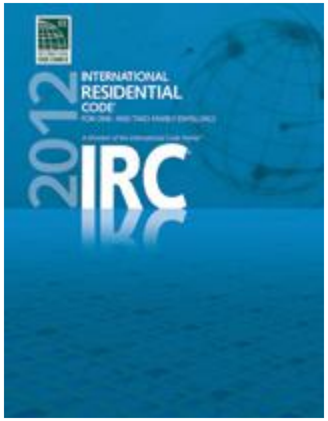


CRAWL SPACE - VAPOR RETARDER OVER SOIL

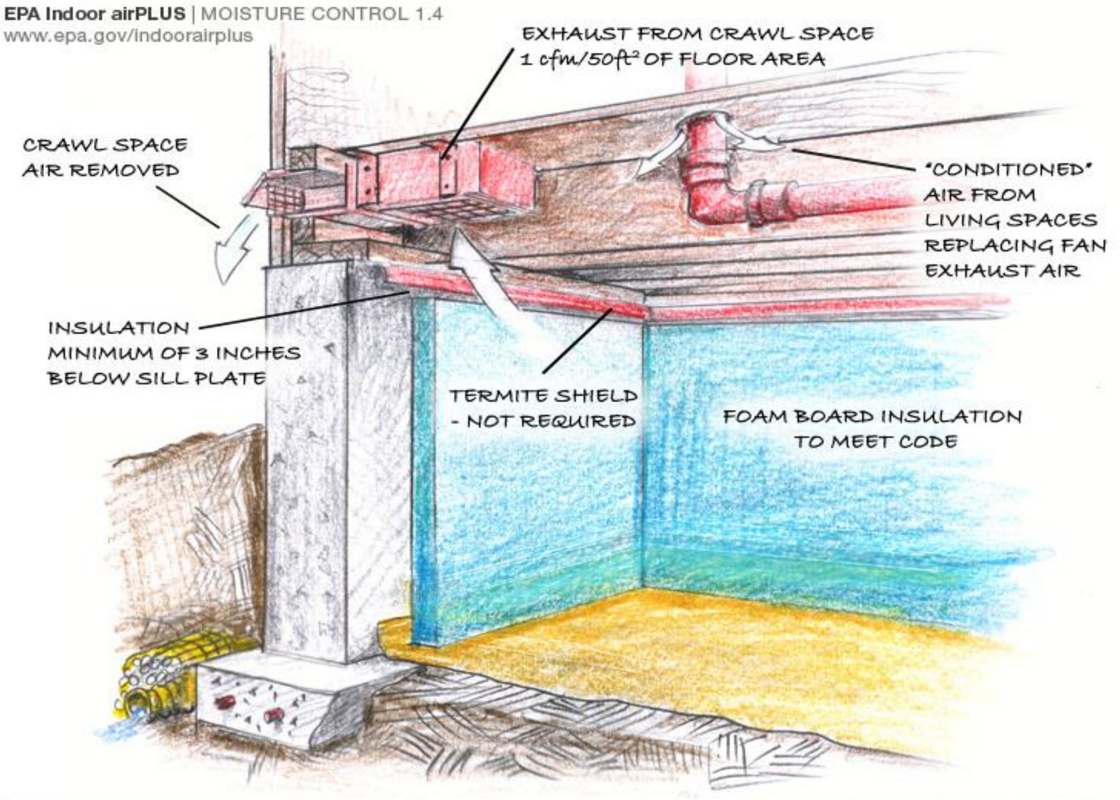
UNVENTED EXCEPTION, PART 2.1

2. One of the following is provided for the under-floor space:

    2.1. Continuously operated mechanical exhaust ventilation at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7m^2) of crawlspace floor area, including an air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1103.2.1 of this code;



- Arguably, an active radon remediation system could be deemed continuously operated mechanical exhaust ventilation



EXHAUST FAN FOR SEALED CRAWL SPACE

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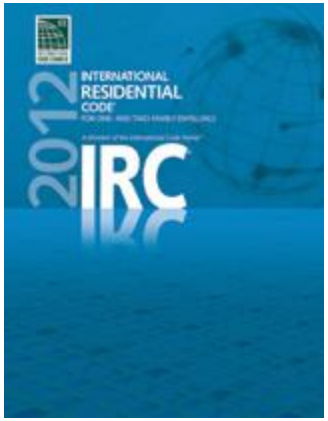
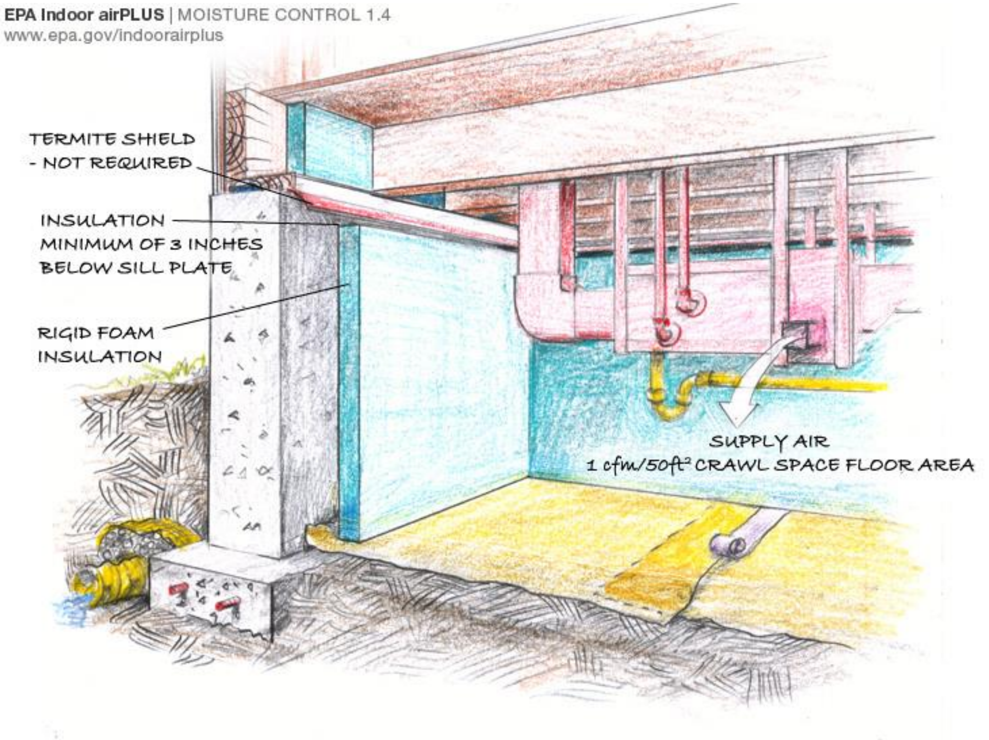
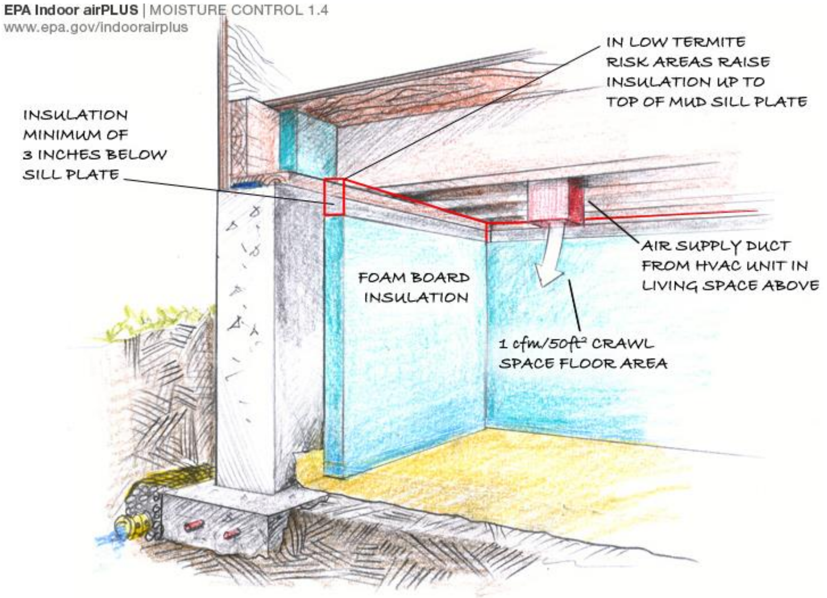
UNVENTED EXCEPTION, PART 2.2



2.2. *Conditioned air* supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m^2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2 of this code;

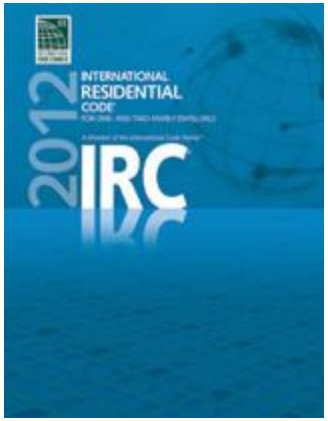


CONDITIONED AIR SUPPLY TO SEALED CRAWL SPACE



CONDITIONED AIR SUPPLY TO SEALED CRAWL SPACE

UNVENTED EXCEPTION, PART 2.2 (WITH A BIT OF AN INTERPRETATION)



2.2. *Conditioned air* supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m^2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2 of this code;

- Arguably, a crawlspace can be “conditioned” by installing a dehumidifier that is delivering the required cfm
- Especially in mixed or warmer climates,
  - drying the crawl air is more important
  - since the walls are insulated, the crawlspace temperature should remain reasonable (above 60 º F)
  - duct leakage contributes to “conditioning”
- Our preferred approach since crawl gets what it needs (moisture control) based on sensor located in the crawlspace itself

UNVENTED EXCEPTION, PART 2.3

2.3. Plenum in existing structures complying with Section M1601.5, if under-floor space is used as a plenum.

TO CLOSE UP OR NOT?

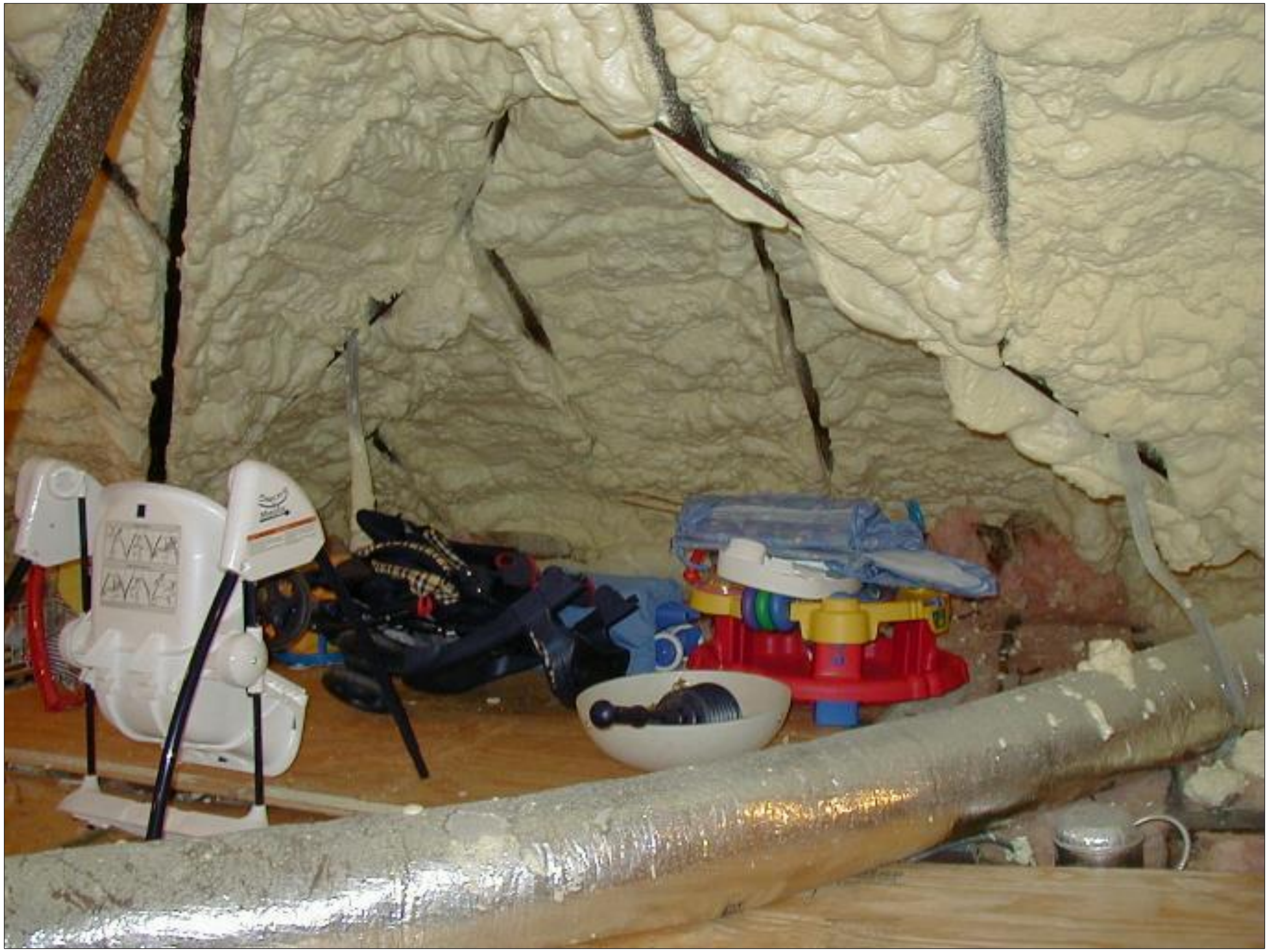
Is it practical to close all crawlspaces?

- Drainage problems
- Combustion safety
- Pest control
- Approval from code officials

EXISTING BUILDINGS

- Drill & fill
- Loose fill (overlay)
- Kneewalls
- Foaming rooflines

INSULATING THE ROOFLINE



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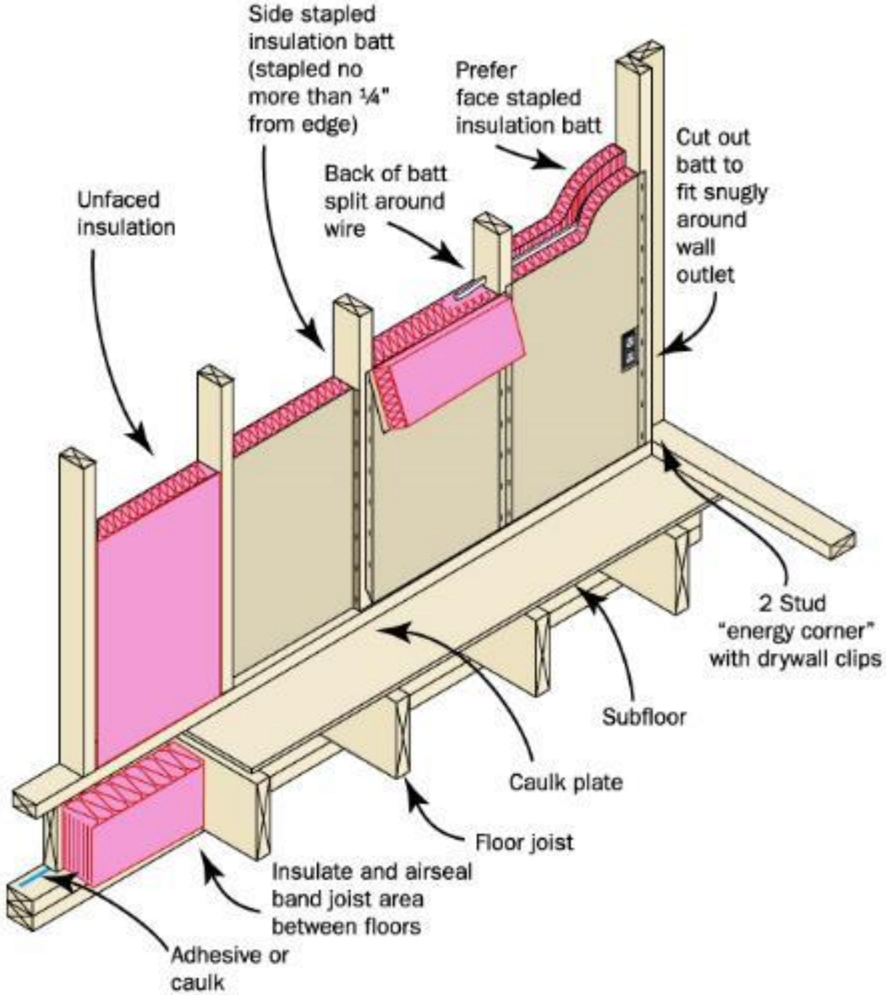
INSPECTION

Let’s put all this theory to work!

PROPER INSULATION INSTALLATION?

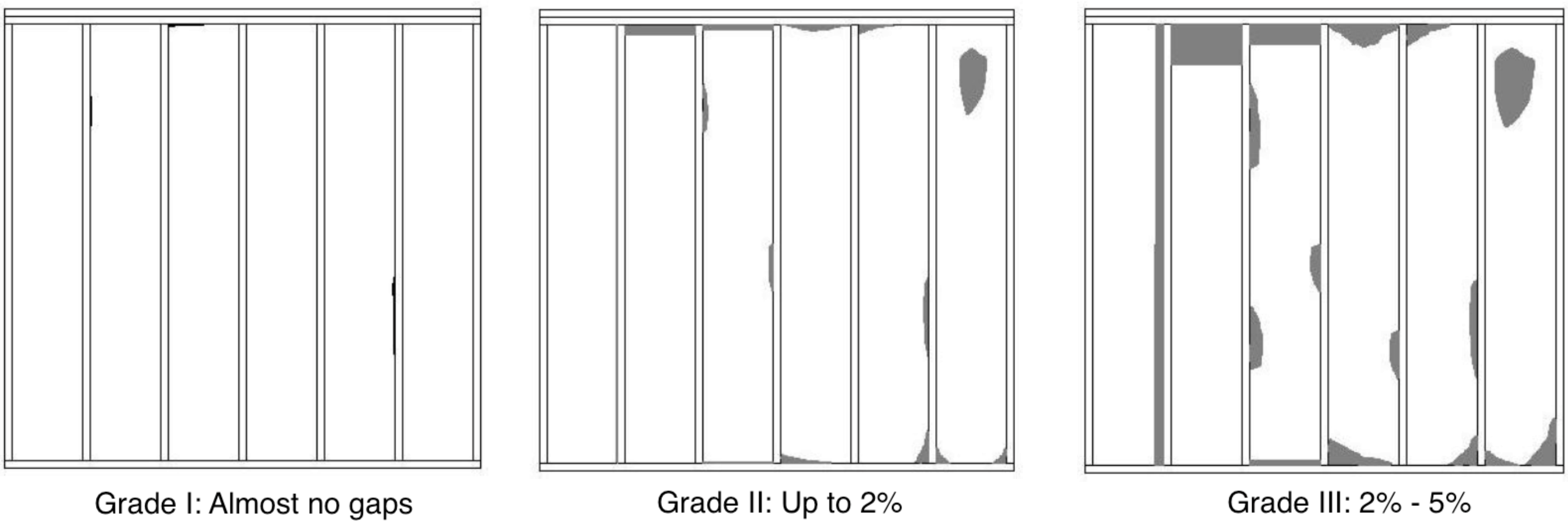
INSTALL INSULATION CORRECTLY

- No gaps
- Cut around plumbing, electrical wiring and outlets
- Compressed insulation reduces R-Value



Southface

INSPECTION



RESNET protocol for the effect of missing insulation on installation grade

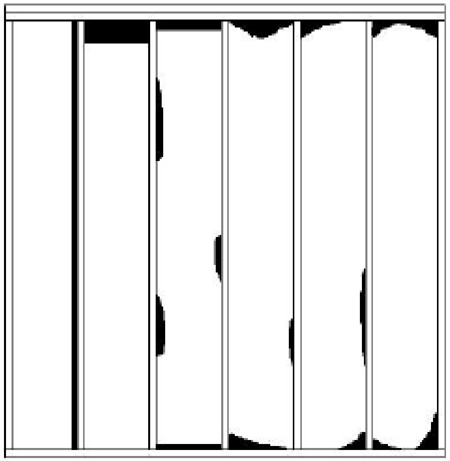
Diagrams from the HERS Standards

NAIMA: insulationinstitute.org
Building America: basc.pnnl.gov

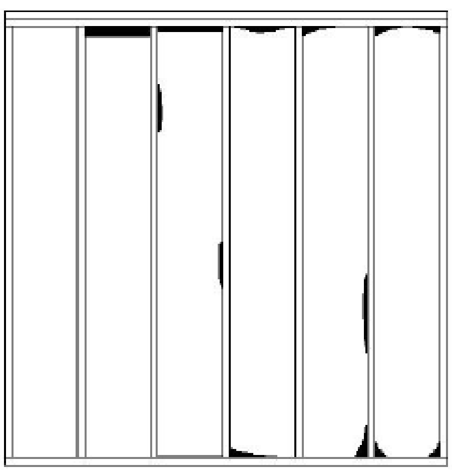
INSULATION INSTALLATION: GRADE

Unless verified, assume Grade III (worst) – see Appendix A-11-16

installation shall be *at least* this good to be labeled as "Grade III":

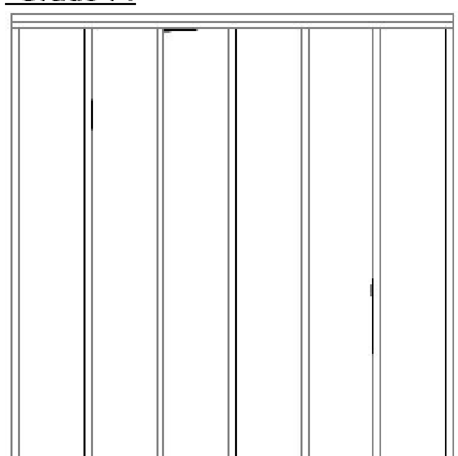


"Grade II":



No more than 2% of surface area of insulation missing is acceptable for "Grade II"

"Grade I":



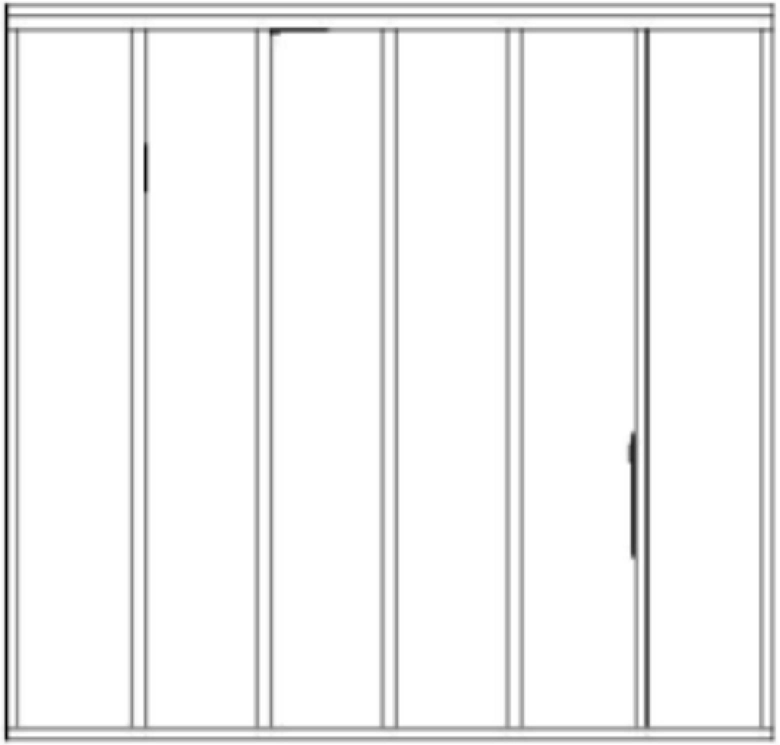
Occasional very small gaps are acceptable for "Grade I".

GRADE I

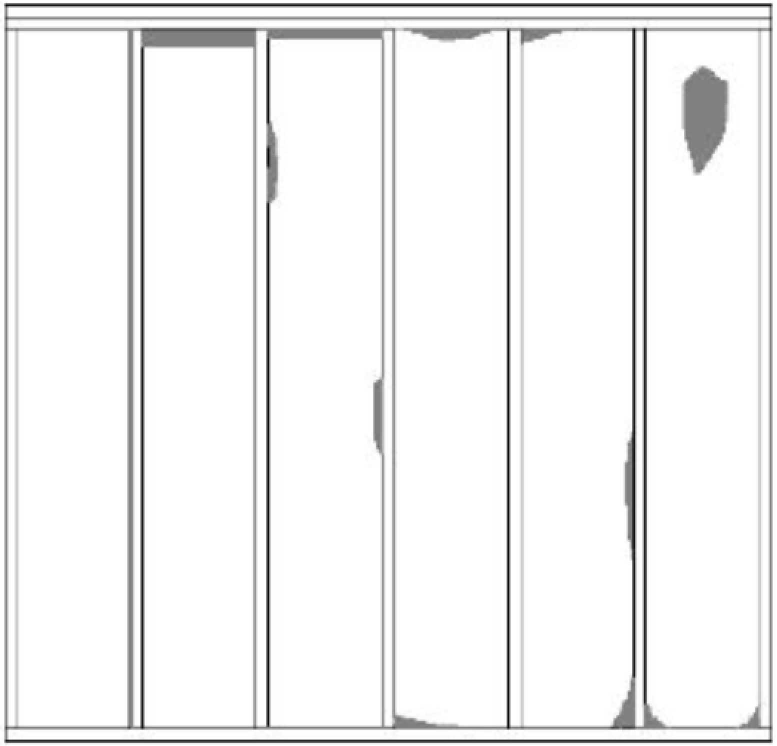
Appendix A-11 - A-13

occasional very small gaps

less than 2% compression/incomplete fill (which may not be more than 30% compressed)



Gaps



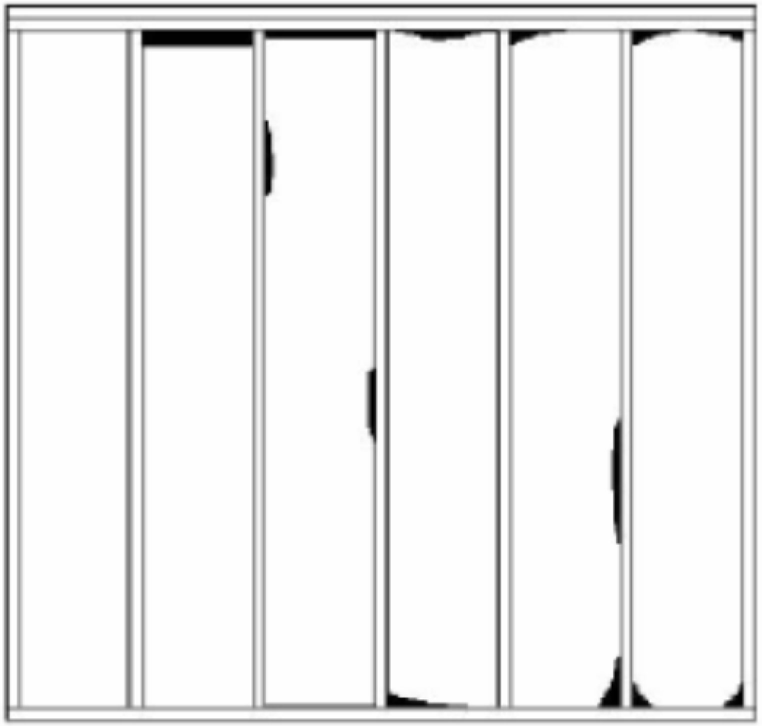
Compression

GRADE II

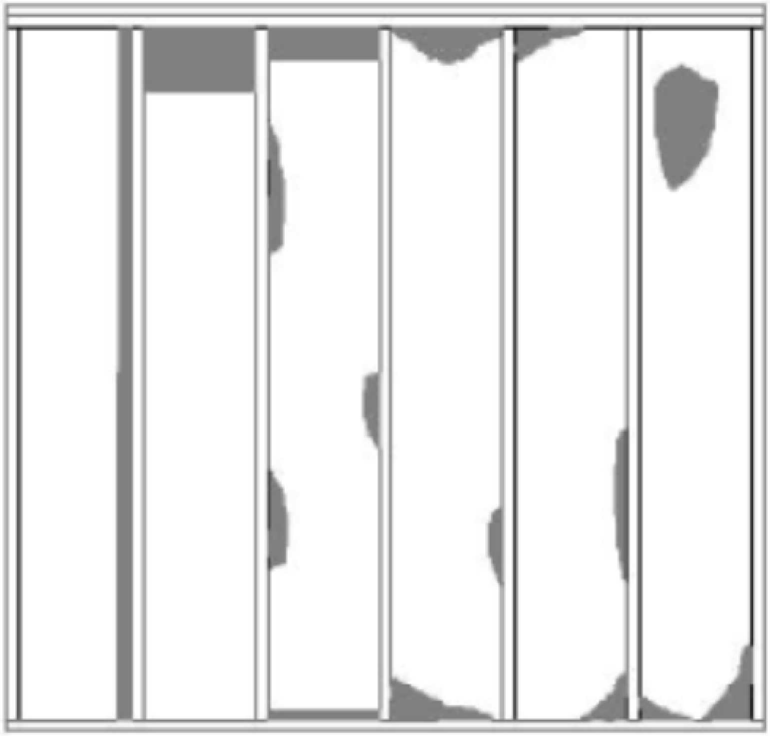
Appendix A-13 - A-15

<2% gaps

<10% compression/incomplete fill
(which may not be more than 30% compressed)



Gaps



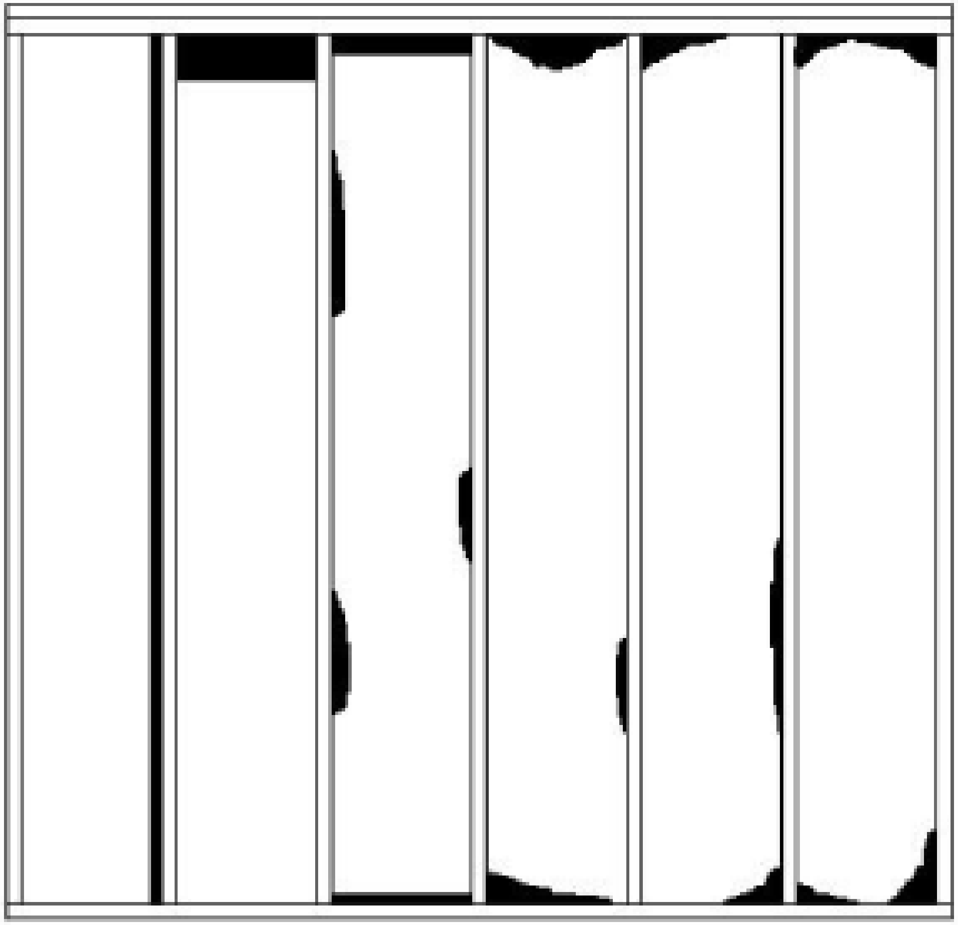
Compression

GRADE III

Appendix A-15 - A-16

> 2% and < 5% gaps

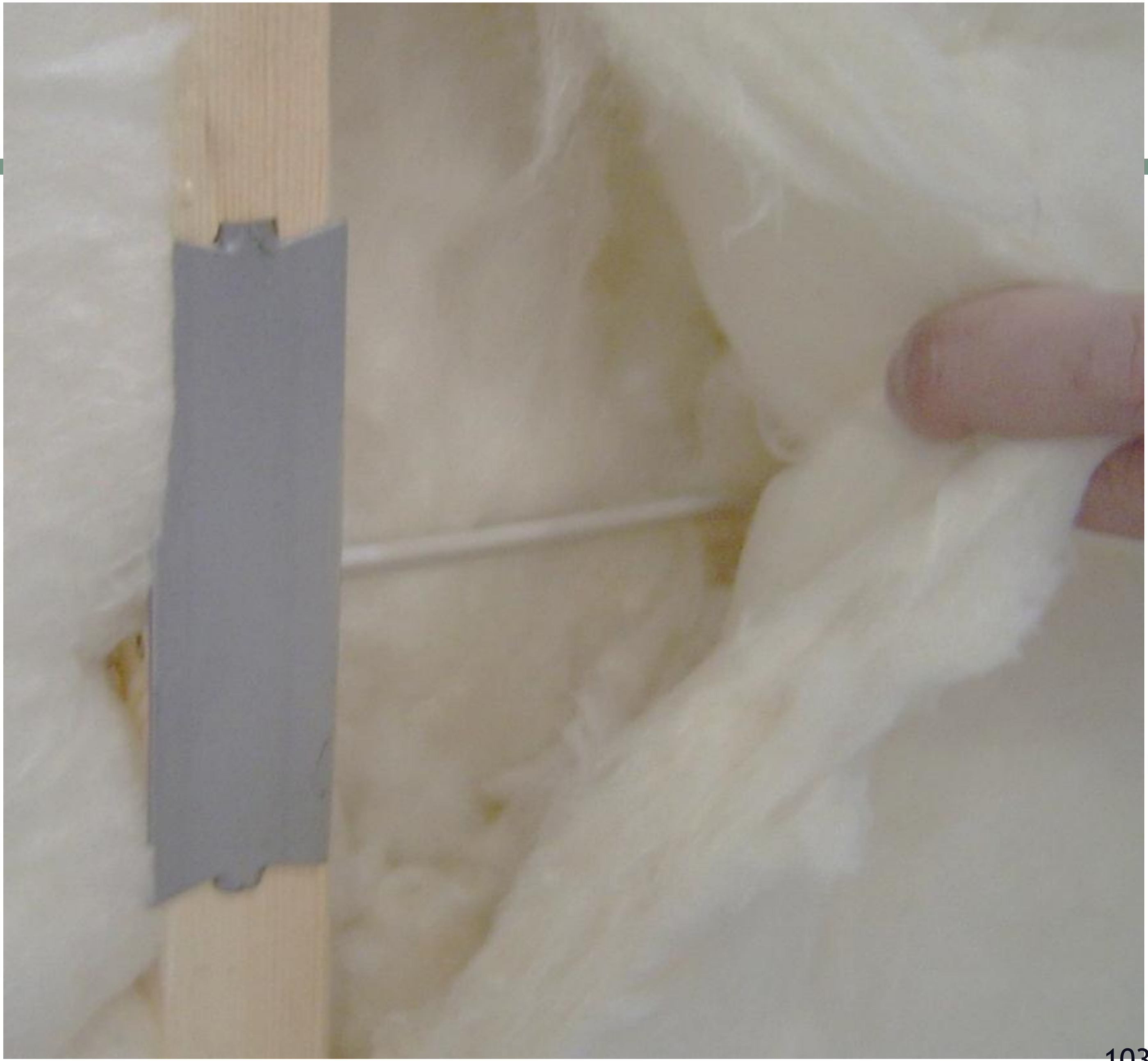
(greater than 5% = downgraded R-value)



Gaps

WHAT GRADE?

WHAT GRADE?



What Grade?

WHAT GRADE?

WHAT GRADE?

WHAT GRADE?

WHAT GRADE?

WHAT GRADE?

SUMMARY

- The building thermal envelope is comprised of both pressure & thermal boundaries (air barrier & insulation).
- The air barrier & insulation should be complete and aligned with each other.
- If there is a pathway, natural & man-made pressure differences will cause air movement between the interior and exterior of homes.
- For best performance, homes should be extensively air sealed and provided with controlled ventilation systems. (required when $ACH_{50}<5$).
- There are a variety of insulation and air sealing materials and products. Each of them must be installed according manufacturer's instructions to provide rated performance.
- An inspection of the building envelope should note unsealed penetrations, seams, etc. and evaluate insulation for complete coverage and proper installation.

QUESTIONS OR COMMENTS?